Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California

(January 2010)

Region 8
U.S. Fish and Wildlife Service
Sacramento, California

Approved:____

Regional Director, Pacific Southwest Region, Region 8,
U.S. Fish and Wildlife Service

Date:___________________________________

Disclaimer

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than the Service. They represent the Service's official position ***only*** after they have been signed by the Director, Regional Director as ***approved.*** Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery action.

Notice of Copyrighted Material

Literature Citation should read as follows:

U.S. Fish and Wildlife Service. 2009. Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California. xviii + 636 pp.

An electronic copy of this draft recovery plan will be made available at
http://www.pacific.fws.gov/ecoservices/endangered/recovery/plans.html and
http://endangered.fws.gov/recovery/index.html#plans

Request for Comments

The U.S. Fish and Wildlife Service (Service) is requesting comments on the *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California.* The draft recovery plan includes the federally endangered California clapper rail (*Rallus longirostrus obsoletus*), salt marsh harvest mouse (*Reithrodontomys raviventris*), California sea-blite *(Suaeda californica*), soft bird's-beak *(Cordylanthus mollis* ssp. *mollis*), Suisun thistle *(Cirsium hydrophilum* var. *hydrophilum*) and the Morro Bay population of salt marsh bird's-beak *(Corylanthus maritimus* ssp. *maritimus*). In addition, six associated federally listed species and 11 non-listed species are considered in this draft recovery plan and its appendices.

One of the most challenging emerging threats to the species discussed in this draft recovery plan is climate change. Climate change science is rapidly evolving. Projections of the specific effects of climate change and the timeframe in which they may occur at any particular location are likely to be uncertain. Because of this uncertainty, determining how to ameliorate effects of climate change is complex. We have discussed climate change and have included actions to address its effect in this draft recovery plan. However, because of the complexity of this threat and how difficult it is to specifically project and address, we particularly seek assistance and comment on this aspect of the draft recovery plan, as indicated below.

Any information you may have regarding the following would be appreciated:

> (1) Biological, commercial trade, or other relevant data concerning any threat (or lack thereof) to the species noted above;
>
> (2) Feedback on the durability of the science regarding climate change and its treatment presented in the draft recovery plan and comments on how best to ameliorate threats to the species in that regard;
>
> (3) Additional information concerning the range, distribution, and population size of these species, including the location of any additional populations;
>
> (4) Current or planned activities in the subject area and their possible impacts on these species; and
>
> (5) The suitability and feasibility of the recovery criteria, strategies, or actions described in the Draft Plan.

A notice has been published in the Federal Register indicating the availability of this plan and when the comment period will be closing.

Draft Recovery Plan Preparation

The publication of the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California is the culmination of a multiyear effort. We intend for this document to be both detailed and current in its presentation of scientific knowledge. However, we recognize the challenge of maintaining an up-to-date document in the face of rapidly changing science, particularly in regards to climate change. Therefore, we welcome public review of this draft as an opportunity to gather both new information and feedback on the durability of the science presented.

While acknowledging the reality of changing scientific understanding, this document includes restoration maps which take into account anticipated sea level rise to the best of our knowledge. The maps are an illustration of one potential vision by which recovery may be achieved. The maps delineate our current understanding of the highest priority areas for protection or restoration of *tidal marsh* or associated habitats. Lands within the recovery unit boundaries have been defined by the range of historic *tidal marsh*. We recognize that not all lands within the boundaries will be necessary for species recovery and that alternative recovery strategies may become necessary as new scientific information becomes available. We look forward to receiving public comment in our efforts to incorporate this critical emerging science.

Numerous individuals have contributed to the authorship of the Draft Recovery Plan for Tidal Marsh Ecosystems of Central and Northern California over a period of many years.
The individuals primarily responsible for finalizing this draft recovery plan are listed in alphabetical order below with sincere apologies to anyone whose name was omitted inadvertently from this list.

U.S. Fish and Wildlife Service: Peter Baye (formerly), Valary Bloom, Brian Cordone
Contractors: Laurie Litman, Howard Shellhammer, Stuart Weiss, David Wright

Acknowledgements

The recovery planning process has benefitted from the collaboration, advice, and assistance of many individuals, agencies, and organizations over the past several years. We thank the following individuals for their assistance and apologize to anyone whose name was omitted inadvertently from this list (*U.S. Fish and Wildlife Service personnel in italics*):

Terry Adelsbach — Sacramento Fish and Wildlife Office
Joy Albertson — Don Edwards San Francisco Bay National Wildlife Refuge
Craig Aubrey — Sacramento Fish and Wildlife Office
Laureen Barthman-Thompson — California Department of Fish and Game
Roxanne Bittman — California Department of Fish and Game
Giselle Block — San Pablo Bay National Wildlife Refuge
Cecelia Brown — Bonneville Power Administration
Randy Brown—Arcata Fish and Wildlife Office
James Browning — Sacramento Fish and Wildlife Office
Joelle Buffa — Don Edwards San Francisco Bay National Wildlife Refuge

Steve Chappell — Suisun Resource Conservation District
Becky Christensen — Elkhorn Slough Ecological Reserve
Josh Collins — San Francisco Estuary Institute
Ron Duke — HT Harvey and Assoc.
Diane Elam — U.S. Fish and Wildlife Service, Pacific Southwest Region
Janice Engle — Sacramento Fish and Wildlife Office
Sarah Estella — California Department of Fish and Game
Jules Evens — Avocet Research Associates
Gary Flaxa — Arcata Fish and Wildlife Office
Brenda Grewell —Univeristy of California, Davis
Melissa Helton — Sacramento Fish and Wildlife Office
Mark Herzog — Point Reyes Bird Observatory
Carin High — private citizen
Josh Hull— Sacramento Fish and Wildlife Office
Rachel Hurt —Alameda and Antioch Dunes National Wildlife Refuge
John Krause — California Department of Fish and Game
Florence La Riviere — Citizens Committee to Complete the Refuge
Harry McQuillen — *Sacramento Fish and Wildlife Office*
Clyde Morris — Don Edwards San Francisco Bay National Wildlife Refuge
Eric Nelson — Arcata Fish and Wildlife Office
Peggy Olofson — San Francisco Invasive Spartina Project
Gary Page — Point Reyes Bird Observatory
Barb Peichel — Elkhorn Slough Ecological Reserve
Andrea Pickart— Humboldt Bay National Wildlife Refuge
Patty Quickert — California Department of Water Resources
Andrew Raabe— Sacramento Fish and Wildlife Office
Barbara Ransom — Cargill Salt
Steve Ritchie- California Coastal Conservancy
Steve Rottenborn — HT Harvey and Assoc.
Connie Rutherford — Ventura Fish and Wildlife Office
Howard Shellhammer— private citizen
Stuart Siegel — Wetlands and Water Resources, Inc.
Christy Smith — San Pablo Bay National Wildlife Refuge
Dale Steele — California Department of Fish and Game
Mendel Stewart — San Francisco Bay National Wildlife Refuge
Kirsten Tarp — Sacramento Fish and Wildlife Office
John Takekawa — United States Geological Service
Lynne Trulio — San Jose State University
Julie Vanderweir — Ventura Fish and Wildlife Office
Gina Van Klompenburg — California Department of Fish and Game
Mike Walgren — California Department of Parks and Recreation
Gary Wallace — Carlsbad Fish and Wildlife Office
Kerstin Wasson — Elkhorn Slough Ecological Reserve
Jim Watkins — Arcata Fish and Wildlife Office
Carl Wilcox — California Department of Fish and Game
Janet Whitlock — Sacramento Fish and Wildlife Office

Dedication

This draft recovery plan is dedicated to Philip and Florence LaRiviere and Frank and Janice Delfino, who have spent countless hours protecting and restoring the habitats and species of the San Francisco Bay. The LaRivieres and Delfinos have spearheaded many efforts, dating back to the 1960s, passionately lobbying for, and increasing public understanding and appreciation of, the ecosystems of the Bay. As cofounders of the Citizens' Committee to Complete the Refuge, they were instrumental in establishing the Don Edwards San Francisco Bay National Wildlife Refuge and have worked tirelessly since then to facilitate its development. The U.S. Fish and Wildlife Service extends its thanks to Philip, Florence, Frank, and Janice for their constant support and applauds their many years of selfless commitment toward the protection and recovery of the *tidal marsh* ecosystem of the San Francisco Bay.

Executive Summary

The *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* features five endangered species. The biology of these species is at the core of the draft recovery plan, but the goal of this effort is the comprehensive restoration and management of *tidal marsh*[1] ecosystems.

This draft recovery plan is an expansion and revision of *The California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* (U.S. Fish and Wildlife Service 1984). The historic distribution of the California clapper rail encompasses major *tidal* salt marshes between Humboldt Bay and, arguably, Morro Bay, defining the approximate geographic scope of this draft recovery plan. The plan also covers three focal listed plant species that were listed as federally endangered in the 1990s and the northernmost *population* of an additional plant species. Two of the species, *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle) and *Cordylanthus mollis* ssp. *mollis* (soft bird's-beak), are restricted to the northern reaches of the San Francisco Bay Estuary. The other endangered *tidal marsh* plant, *Suaeda californica* (California sea-blite), historically occurred in both San Francisco Bay and Morro Bay but, except for three *reintroductions* to San Francisco Bay, is now restricted to Morro Bay. Another federally listed plant, *Cordylanthus maritimus* ssp. *maritimus* (salt *marsh* bird's-beak), has its northern range limit in Morro Bay. Morro Bay was omitted from the *Salt Marsh Bird's Beak Recovery Plan* (U.S. Fish and Wildlife Service 1985*a*) because the taxonomic interpretation at the time classified this *population* in another subspecies that is not federally listed. Current taxonomic interpretation considers the Morro Bay *population* as *Cordylanthus maritmus* ssp. *maritimus*. It is included in this draft recovery plan due to its co-location with *Suaeda californica* in Morro Bay. Though recovery strategies and actions are provided for the Morro Bay *population* of *Cordylanthus maritimus* ssp. *maritimus*, recovery criteria are not, therefore, the species should not truly be considered covered by the recovery portion of the document.

In addition, this draft recovery plan addresses 11 species of concern. These include the salt *marsh* wandering shrew (*Sorex vagrans halicoetes*) and Suisun shrew (*Sorex ornatus sinuosus*), San Pablo vole (*Microtus californicus sanpabloensis*), California black rail (*Laterallus jamaicensis coturniculus*), three song sparrow subspecies of the San Francisco Bay Estuary (*Melospiza melodia* spp.), saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*), old man tiger beetle (*Cicindela senilis senilis*), *Lathryrus jepsonii* ssp. *jepsonii* (delta tule pea), and *Spartina foliosa (*Pacific cordgrass).

These species occur in a variety of *tidal marsh* habitats where they are limited by the requirements of moisture, *salinity,* topography, soil types, and climatic conditions. Adjacent *uplands* and *ecotone* areas are also crucial habitats for many of these species. Primary threats to all the listed species include historical and current habitat loss and fragmentation due to urban development, agriculture, and diking related to duck hunting; altered *hydrology* and *salinity*; *non-native invasive* species; inadequate regulatory mechanisms; disturbance; contamination; sea level rise due to climate change; and risk of extinction due to vulnerability of small *populations* in the face of random naturally occurring events.

[1] With the exception of scientific names, words in italics are defined in the Glossary (Appendix G).

Current Species Status

Cirsium hydrophilum var. *hydrophilum—Cirsium hydrophilum* var. *hydrophilum* was designated as endangered in its entire range on November 20, 1997. It was once widespread in Suisun Marsh, but in the last two decades has been found in only four localities: Grizzly Island, Peytonia Slough, Rush Ranch, and, Hill Slough. These *populations* have been in decline in the 1990s and 2000s.

Cordylanthus mollis ssp. *mollis—Cordylanthus mollis* ssp. *mollis* was designated as endangered in its entire range on November 20, 1997. Persistent *populations* have been recorded in the *tidal* marshes of Napa-Sonoma, Point Pinole, Carquinez Staits, Suisun Marsh area, and northern Contra Costa County. These *populations* are composed of many shifting colonies or *subpopulations*, with great variability in *population* size and distribution. Currently 11 *populations* are believed to be extant.

Suaeda californica—Suaeda californica was designated a federally endangered species over its entire range on December 15, 1994. It occurred historically in high salt *marsh* in portions of San Francisco Bay, where it became nearly extinct because of habitat loss. Due to several *reintroductions* between 1999 and 2008, it is currently known from three sites in the San Francisco Bay and scattered locations along the shoreline of Morro Bay, San Luis Obispo County.

California clapper rails—California clapper rails were designated as federally endangered on October 13, 1970. Historically, the range may have extended from salt marshes of Humboldt Bay to Morro Bay. San Francisco Bay has been the center of its abundance. The California clapper rail now occurs only within the *tidal* salt and *brackish* marshes around San Francisco Bay where it is restricted to less than 10 percent of its former geographic range. Densities reached an all-time historical low of about 500 birds in 1991, then rebounded somewhat, however the most recent survey estimated only 543 birds in the San Francisco Bay Estuary (http://www.prbo.org).

Salt marsh harvest mouse—Both subspecies of the salt *marsh* harvest mouse were designated a federally endangered species on October 13, 1970. The two subspecies are restricted to the salt and *brackish* marshes of San Francisco, San Pablo, and Suisun Bay areas. The southern subspecies inhabits central and south San Francisco Bay, and has suffered severe habitat loss and fragmentation. Less than 10 percent of its historic habitat acreage remains, and nearly all is deficient in its structural suitability. The northern subspecies, living in the marshes of San Pablo and Suisun bays, has also sustained extensive habitat loss and degradation, but less so than the southern subspecies.

Habitat Requirements and Limiting Factors

Cirsium hydrophilum var. *hydrophilum—Cirsium hydrophilum* var. *hydrophilum* grows in the upper middle *marsh plain* and high *marsh*, usually associated with small *tidal* creek banks that locally drain the *marsh* peat surface. Its extreme historical decline was due to diking and reclamation of nearly all the *tidal* marshes in Suisun Marsh for either agriculture or waterfowl production and sport hunting under nontidal, nearly *freshwater* management. Immediate threats include precariously low numbers, confined dispersal of its seeds in limited habitat, introduced *non-native* insect seed predators, and interference with its regeneration caused by *non-native invasive marsh* vegetation. Other threats include invasion by *non-native Lepidium latifolium* (perennial pepperweed)*,* disturbance, *salinity* changes, and *genetic* swamping by by *non-native* thistle species.

Cordylanthus mollis ssp. *mollis—Cordylanthus mollis* ssp. *mollis* occurs in high salt and *brackish tidal marsh* of northern San Pablo Bay and the Suisun Marsh area, and in some *diked brackish* marshes with limited *tidal* circulation. It has an affinity for the higher well-drained portions of the *marsh* and the edges of *salt pans*. It occurs primarily in portions of the middle to high *marsh* zones where the dominant vegetation includes gaps and areas of sparse vegetative canopy cover, often in association with *Sarcocornia pacifica* (pickleweed) and *Distichlis spicata* (saltgrass). It is negatively associated with dense, tall grass-like vegetation and dense or tall *non-native brackish marsh* vegetation (as these dense vegetation types increase in abundance the abundance of *Cordylanthus mollis* ssp*. mollis* decreases). Isolation of *populations* by *dikes* and non-*tidal marsh* management limits its potential dispersal to suitable habitat. It is endangered by low *population* numbers, severely reduced habitat area, and reduced habitat quality. Invasion by *non-native tidal marsh* vegetation and *hydrologic* alterations to *tidal sloughs* are significant threats to remaining habitat.

Suaeda californica—Suaeda californica occupies a narrow zone at the upper edge of salt *marsh*, and prefers coarse *marsh sediments* or sheltered estuarine beaches. It requires well-drained *marsh* substrates, primarily sandy wave-built *berms* or ridges along *marsh* banks, and estuarine beaches. Because its habitat is naturally prone to destruction by wave erosion, it needs widespread *populations* in diverse environments over large areas to enable it to recolonize by seed after some *populations* are destroyed by storms. It is endangered in Morro Bay by shoreline development, storm erosion, and interference with seedling regeneration caused by *invasive non-native* vegetation (mostly *Carprobrotus eduli*s [iceplant]). Artificial stabilization of sandy shores, or other static modification of suitable estuarine shorelines, threatens the *resilience* of its *population* in Morro Bay, and could constrain its recovery in San Francisco Bay.

California clapper rails—California clapper rails occur almost exclusively in *tidal* salt and *brackish* marshes with unrestricted daily *tidal*flows, adequate invertebrate prey food supply, well developed *tidal* channel networks, and suitable nesting and escape cover as *refugia* during extreme high *tides*. *Non-native* mammalian predators are a significant threat to the species. Lack of extensive blocks of *tidal marsh* with suitable structure is the ultimate limiting factor for the species' recovery; vulnerability to predation is exacerbated by reduction of clapper rail habitat to narrow and fragmented patches close to urban edge areas that diminish habitat quality. *Dikes* provide artificial access for terrestrial predators, and displace optimal cover of high *marsh* vegetation. The rapid invasion of San Francisco Bay by exotic *Spartina alterniflora* (smooth cordgrass) also threatens to cause major long-term structural changes in *tidal* salt *marsh* creek beds and banks, *slough* networks, and *marsh* plains, and could impair future habitat for California clapper rails. Contaminants, particularly methylmercury, are a significant factor affecting viability of California clapper rail eggs.

Salt marsh harvest mouse—The salt *marsh* harvest mouse is generally restricted to saline or *subsaline marsh* habitats around the San Francisco Bay Estuary and, with some exception, mixed saline/*brackish* areas in the Suisun Bay area. The distribution in *tidal*and *diked* marshes closely corresponds with the abundance of *Sarcocornia*, a dominant plant species of salt marshes and a common component of *brackish marsh* vegetation. *Viable populations* of salt *marsh* harvest mice also appear to be limited by the distribution of high *tide* cover and *escape habitat*. Recurrent but shallow flooding by saline water is probably needed to maintain habitat that favors the salt *marsh* harvest mouse over its potential competitors.

Recovery Strategy

Recovery units have been designated for most species covered in this draft recovery plan (see **Table III-1**). Recovery of each listed species discussed in this draft recovery plan depends upon satisfying the recovery criteria within each recovery unit for the given species. Although recovery units are not designated for non-listed species, the establishment of recovery units for the listed species will assist in meeting conservation objectives for the non-listed species as well.

Maintaining well-distributed *populations* throughout the geographic range of each species is necessary for the long-term recovery of the listed species covered in this draft recovery plan. To ensure that each *taxon* can persist depite weather variations, climate change, or *catastrophic* events, the suite of microhabitats in recovery areas should represent the full range of environmental conditions in which the *taxon* occurred historically. The range of *genetic* variation must also be maintained to minimize the risk of *inbreeding depression* and allow for evolution and *resilience* to environmental change.

Recovery Priority Numbers

Recovery priority numbers are determined per criteria published in the Federal Register (U.S. Fish and Wildlife Service 1983), as described in **Appendix B**. Recovery priority numbers for the focal listed species are:

- *Cirsium hydrophilum* var *hydrophilum* = 3C
- *Cordylanthus mollis* ssp. *mollis* = 9C
- *Suaeda californica* = 8
- California clapper rail = 3C
- Salt marsh harvest mouse = 2C

Recovery Goals

The ultimate goal of this draft recovery plan is to recover all focal listed species so they can be delisted. The interim goal is to recover all endangered species to the point that they can be downlisted from endangered to threatened status. For *Cordylanthus maritimus* ssp. *maritimus*, the goal is to support recovery as described in the Salt Marsh Bird's Beak (*Cordylanthus maritimus* ssp. *maritimus*) Recovery Plan (U.S. Fish and Wildlife Service 1985*a*). For species covered by this draft recovery plan that are not federally listed as threatened or endangered, the goal is to conserve them so as to preclude the need for protection provided by listing.

Recovery Objectives
Within a 50-year planning period (based on estimated time to achieve sufficiently mature restored *tidal marsh* habitats), the Service expects that the following species recovery objectives will be met:

1. Secure self-sustaining wild *populations* of each covered species throughout their full ecological, geographical, and *genetic* ranges.

2. Ameliorate or eliminate the threats, to the extent possible, that caused the species to be listed or of concern and any future threats.

3. Restore and conserve a healthy ecosystem function supportive of *tidal marsh* species.

Recovery objectives for the regional *tidal marsh* ecosystems are implicit in the recovery of their species, and are identified explicitly in recovery strategies, actions, and restoration maps.

Recovery Criteria:
We have identified 5 recovery units: Suisun Bay Area, San Pablo Bay, Central/South San Francisco Bay, Central Coast, Morro Bay. Recovery criteria comprise a combination of numerical *demographic* targets and measures that must be taken to directly ameliorate or eliminate threats to species in the appropriate subset of the above recovery units. They are too varied to summarize consisely here, but see section III.A.3 of this document for detailed information.

Actions Needed:
1.0 Acquire existing, historic, and restorable tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other *tidal marsh* species.

2.0 Protect, manage, restore, and monitor *tidal marsh* habitat to promote the recovery of listed species and the long-term conservation of species of concern and other *tidal marsh* species.

3.0 Conduct range-wide species status surveys/monitoring and status reviews for listed species and species of concern covered in this draft recovery plan.

4.0 Conduct research necessary for the recovery of listed species and the long-term conservation of the species of concern covered in this draft recovery plan.

5.0 Improve coordination, participation, and outreach activities to achieve recovery of listed species and long-term conservation of species of concern covered in this draft recovery plan.

Estimated Cost of Recovery:
Priority 1 actions: $847,320,390
Priority 2 actions: $441,868,550
Priority 3 actions: $6,702,020
Grand Total: $1,295,890,960

Date of Recovery:
If recovery criteria are met, we estimate that most listed species covered in this draft recovery plan could be recovered by 2059 (50 years). If the rates of global warming and consequent sea level rise increase, more time may be required to achieve recovery.

Table of Contents

I. INTRODUCTION **1**

A. Introduction to the California tidal marsh ecosystem 1

a. Scope of the Draft Recovery Plan 2

b. Tidal Marsh Ecosystems of Northern and Central California 4

B. San Francisco Bay Estuary tidal marshes 6

a. Pre-historical and early historical tidal marsh 6

b. Historical tidal marsh loss and degradation around the San Francisco Bay Estuary 10

c. Tidal marsh habitats of the San Francisco Bay Estuary 13

C. Other major tidal marsh ecosystems of the northern and central California coast 16

a. Humboldt Bay 16

b. North coast stream mouth estuaries and lagoons 19

c. Marin-Sonoma coast 19

d. San Mateo coast 23

e. Monterey Bay (Elkhorn Slough, Salinas River mouth) 23

f. Morro Bay 24

D. Threats to California tidal marsh ecosystems 26

Factor A: The present destruction, modification, or curtailment of its habitat or range. 26

Factor B: Overutilization for Commercial, Scientific or Educational purposes. 38

Factor C: Disease or Predation 39

Factor D: Inadequacy of Existing Regulatory Mechanisms 39

Factor E: Other Natural or Manmade Factors Affecting its Continued Existence 40

E. Tidal marsh conservation, restoration, and management 45

II. SPECIES ACCOUNTS **53**

A. Focal Listed Species 53

a. *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle) 53

1) Brief Overview 53

2) Description and Taxonomy 53

3) Population Trends and Distribution 56

4) Life History and Ecology 58

5) Habitat Characteristics/Ecosystem 60

6) Critical Habitat 61

7) Reasons for Decline and Threats to Survival 61

b. Cordylanthus mollis ssp. mollis **(soft bird's-beak)** 65

1) Brief Overview 65

2) Description and Taxonomy 65

3) Population Trends and Distribution 67

4) Life History and Ecology 69

5) Habitat Characteristics/Ecosystem 73

6) Critical Habitat 75

7) Reasons for Decline and Threats to Survival 75

c. Suaeda californica **(California sea-blite)** 80

1) Brief Overview 80

2) Description and Taxonomy 80

3) Population Trends and Distribution 82
4) Life History and Ecology 85
5) Habitat Characteristics/Ecosystem 88
6) Critical Habitat 90
7) Reasons for Decline and Threats to Survival 90

***d.* California Clapper Rail (*Rallus longirostris obsoletus*) 93**
1) Brief Overview 93
2) Description and Taxonomy 94
3) Population Trends and Distribution 95
4) Life History and Ecology 101
5) Habitat Characteristics/Ecosystem 107
6) Critical Habitat 109
7) Reasons for Decline and Threats to Survival 109

e.* Salt marsh harvest mouse *(Reithrodontomys raviventris) 121
1) Brief Overview 121
2) Description and Taxonomy 122
3) Population Trends and Distribution 124
4) Life History and Ecology 127
5) Habitat Characteristics/Ecosystem 128
6) Critical Habitat 131
7) Reasons for Decline and Threats to Survival 131

B. *Cordylanthus maritimus ssp. maritimus* (salt marsh bird's-beak) 133
1) Brief Summary 133
2) Description and Taxonomy 133
3) Population Trends and Distribution 135
4) Life History/Ecology 136
5) Habitat Characteristics/Ecosystem 139
6) Critical Habitat 139
7) Reasons for Decline and Threats to Survival 140

III. RECOVERY STRATEGIES 143

A. Recovery Goals, Objectives, and Criteria 143
1. Recovery Goals and Objectives 143
2. Recovery Units 143
Suisun Bay Area Recovery Unit 146
San Pablo Bay Recovery Unit 146
Central/South San Francisco Bay Recovery Unit 146
Central Coast Recovery Unit 147
Morro Bay Recovery Unit 147
3. Recovery Criteria 153
a. *Cirsium hydrophilum* var. *hydrophilum* 153
b. *Cordylanthus mollis* ssp. *mollis* 157
c. *Suaeda californica* 161
d. California clapper rail 167
e. Salt marsh harvest mouse 172

B. Species Recovery and Conservation Strategies 187

1. Ecosystem-level recovery strategies 187
2. Regional-level recovery strategies 194
Humboldt Bay and north coast 194
Suisun Bay Area to the Delta....199
San Pablo Bay....206
Central/Southern San Francisco Bay 211
Central Coast....216
Morro Bay and South Central Coast....221
3. Species-level recovery strategies 223
a. *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle) 223
b. *Cordylanthus mollis* ssp. *mollis* (soft bird's beak)....226
c. *Suaeda californica* (California sea-blite)....230
d. California clapper rail (*Rallus longirostrus obsoletus*)....234
e. Salt marsh harvest mouse (*Reithrodontomys raviventris*) 239
f. *Cordylanthus maritimus* ssp. *maritimus* (salt marsh bird's beak) 248
C. Restoration Maps....249

IV. STEPDOWN NARRATIVE 277

V. IMPLEMENTATION SCHEDULE 325

VI. LITERATURE CITED 377

List of Tables

Table II-1 Summary of field characters for discrimination between *Cirsium vulgare* and *Cirsium hydrophilum* var. *hydrophilum* populations found in Suisun Marsh, Solano County, California. 55

Table II-2 Summary of California clapper rail reproductive success (percent) San Francisco Bay. 103

Table II-3 Clapper rail nest fate summary table. 104

Table II-4 Recent estimates of California clapper rail breeding densities in San Francisco Bay. 106

Table II-5 Key field characters distinguishing between the salt marsh harvest mouse and western harvest mouse 123

Table III-1 Recovery units included in this draft recovery plan and listed species known to occupy each recovery unit 144

Table III-2 Summary of recovery criteria for *Cirsium hydrophilum* var. *hydrophilum, Cordylanthus mollis* ssp. *mollis,* and *Suaeda californica* 164

Table III-3 Summary of recovery criteria for California clapper rail and salt marsh harvest mouse…………………………………………………………………….................181

Table III-4 Regional Species Planning Checklist: Humboldt Bay and North Coast………....195

Table III-5 Regional Species Planning Checklist: Suisun Bay Area to the Delta.....................199

Table III-6 Regional Species Planning Checklist: San Pablo Bay ....…………........206

Table III-7 Regional Species Planning Checklist: Central/South San Francisco Bay 211

Table III-8 Regional Species Planning Checklist: Central Coast......……………………..........216

Table III-9 Regional Species Planning Checklist: Morro Bay....………………………….........221

List of Figures

Figure I-1 Intertidal distribution of the major species covered in this draft recovery plan 1

Figure I-2 Overview of tidal marsh draft recovery plan area. 3

Figure I-3 Tidal datums.. 5

Figure I-4 Invasive *Spartina*. 31

Figure I-5 *Lepidium latifolium*.. 36

Figure I-6 Scenarios of sea-level rise to 2100.. 44

Figure II-1 *Cirsium hydrophilum* var. *hydrophilum*................................ 54

Figure II-2 Distribution of *Cirsium hydrophilum* var. *hydrophilum*. 57

Figure II-3 *Cordylanthus mollis* ssp. *mollis*. 66

Figure II-4 Distribution of *Cordylanthus mollis* ssp. *mollis*. 70

Figure II-5 S*uaeda californica*. 81

Figure II-6 Distribution of S*uaeda californica* near San Francisco Bay 86

Figure II-7 Distribution of S*uaeda californica* near Morro Bay................ 87

Figure II-8 California clapper rail. 95

Figure II-9 Distribution of California clapper rail, overview.................... 99

Figure II-10 Distribution of California clapper rail, San Francisco Bay………..........................100

Figure II-11 Salt marsh harvest mouse.. 123

Figure II-12 Distribution of salt marsh harvest mouse............................... 126

Figure II-13 *Cordylanthus maritimus* ssp. *maritimus*. 134

Figure II-14 Distribution of *Cordylanthus maritimus* ssp. *maritimus* 138

Figure III-1 Overview of tidal marsh ecosystem recovery units 145

Figure III-2 Suisun Bay Area Recovery Unit 148

Figure III-3 San Pablo Bay Recovery Unit.. 149

Figure III-4 Central/South San Francisco Bay Recovery Unit 150

Figure III-5 Central Coast Recovery Unit 151

Figure III-6 Morro Bay Recovery Unit 152

Figure III-7 Restoration map—segment A 251

Figure III-8 Restoration map—segment B 252

Figure III-9 Restoration map—segment C 253

Figure III-10 Restoration map—segment D 254

Figure III-11 Restoration map—segment E 255

Figure III-12 Restoration map—segment F... 256

Figure III-13 Restoration map—segment G 257

Figure III-14 Restoration map—segment H 258

Figure III-15 Restoration map—segment I.. 259

Figure III-16 Restoration map—segment J 260

Figure III-17 Restoration map—segment K 261

Figure III-18 Restoration map—segment L 262

Figure III-19 Restoration map—segment M 263

Figure III-20 Restoration map—segment N 264

Figure III-21 Restoration map—segment O 265

Figure III-22 Restoration map—segment P... 266

Figure III-23 Restoration map—segment Q 267

Figure III-24 Restoration map—segment R 268

Figure III-25 Restoration map—segment S..269

Figure III-26 Restoration map—segment T..270

Figure III-27 Restoration map—segment U..271

Figure III-28 Restoration map—segment V..272

Figure III-29 Restoration map—segment W..273

Figure III-30 Restoration map—segment X..274

Figure III-31 Restoration map—segment Y..275

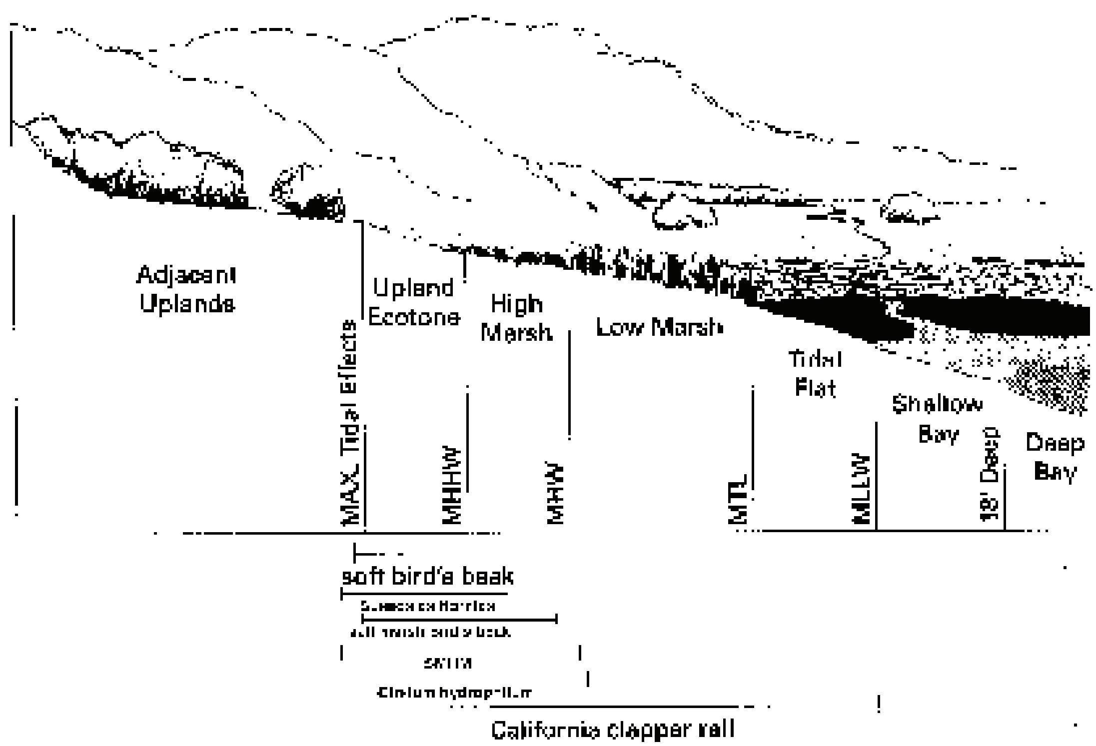
Figure III-32 Restoration map—segment Z..276

I. INTRODUCTION

A. Introduction to the California tidal marsh ecosystem

Balanced between sea and shore, *tidal* marshes form an interesting, scenic, and compelling part of the coastal landscape. Not quite land and not quite water, buffeted by *tides*, waves, sun, and salt, their tenacity fascinates the casual and scientific observer alike.

Technically, *tidal* marshes are vegetated, intertidal, sedimentary wetlands that develop in coastal environments sheltered from high wave energy, with variable ecological influence from marine or estuarine *salinity* (Adam 1990, Ranwell 1972). Fluctuating *salinity* and moisture from daily *tides* support vegetation and fauna adapted to the unique conditions. *Tidal marsh* ecosystems range from salt marshes with *salinity* from about 18 parts per thousand (ppt) salt to near marine concentrations (34 ppt), to *tidal brackish* marshes typically diluted to *salinity* ranges from 3-15 ppt, less than half the concentration of seawater (National Wetlands Research Center 2007), to *tidal freshwater* marshes. *Tidal mudflats* continue beyond *tidal marsh* ecosystems, extending into the lower elevations of the *tidal* gradient (Pethick 1992). The distribution of listed species covered in this draft recovery plan along the *tidal* gradient is shown in **Figure I-1**. A glossary of relevant terms can be found in **Appendix G**. These terms are italicized at first use in the text.



MHHW: Mean higher high water   MTL: Mean tide line   SMHM: salt marsh harvest mouse
MHW: Mean high water   MLLW: Mean lower low water

FIGURE I-1. Intertidal distribution of the major species covered in this draft recovery plan (adapted from Goals Project 1999).

a. Scope of the Draft Recovery Plan

This draft recovery plan addresses endangered and threatened species of *tidal* marshes in California from Humboldt Bay to Morro Bay. Its geographic scope is based principally on the biogeographic unity of this region, common land-use threats to federally listed species, and the shared recovery and conservation requirements of many listed species and species in decline. This area corresponds with the historical distribution of the California clapper rail (*Rallus longirostris obsoletus*); all of the other species considered fall within this range. Southern California *tidal* marshes are ecologically distinct from those further north, and occur in a very different landscape. Morro Bay *tidal* marshes, therefore, set the southern boundary for the geographic scope of this draft recovery plan. **Figure I-2** illustrates the geographic scope of the draft recovery plan.

Ecosystem restoration is the principal means of recovering the listed species *endemic* to *tidal* marshes. The large geographic and ecological scope of ecosystem restoration for *tidal marsh* recovery will necessarily affect other parts and species of the estuaries. Wetland habitats around and within *tidal* marshes must be included in an ecosystem-based approach. Even where habitat boundaries are well-defined, strong links are established by *sediment* transport, nutrient exchanges, and major controlling physical variables of *hydrology*.

This draft recovery plan is an expansion and revision of the *California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* (U. S. Fish and Wildlife Service 1984). It also covers three endangered plant species, *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle), *Cordylanthus mollis* ssp. *mollis* (soft bird's beak), and *Suaeda californica* (California sea-blite), and the northernmost *population* of *Cordylanthus maritimus* ssp. *maritimus* (salt marsh bird's beak).

In addition to the six listed species, other species are covered that may be protected from a need for listing as threatened or endangered by appropriate *tidal marsh* recovery actions. Numerous plant and animal species from *tidal marsh* ecosystems within the geographic range of this draft recovery plan have become rare or are in significant decline. These species are influenced by most of the same major threats that caused the federally endangered species to be listed. These associated *tidal marsh* species of concern (including some *populations* of more wide-ranging species) include the *tidal marsh* shrew species (*Sorex vagrans halicoetes* and *S. ornatus sinuosus*), San Pablo vole (*Microtus californicus sanpabloensis*), California black rail (*Laterallus jamaicensis coturniculus*), three local *tidal marsh* races of song sparrows (*Melospiza melodia* spp.), salt marsh common yellowthroat (*Geothlypis trichas sinusus*), old man tiger beetle (*Cicindela senilis senilis*), *Lathyrus jepsonii* var. *jepsonii* (delta tule pea), and *Spartina foliosa* (Pacific cordgrass).

FIGURE I-2. Overview of tidal marsh draft recovery plan area.

Consideration of the larger ecosystem is also necessary to avoid potential conflicts between recovery needs of endangered *tidal marsh* species and those of federally listed native birds, mammals, and estuarine fish and other species of concern that lack protected legal status. Six federally listed species considered in this draft recovery plan that may be affected by *tidal marsh* ecosystem recovery include the western snowy plover (Pacific coast *population*; *Charadrius alexandrinus nivosus*), California least tern (*Sterna antillarum browni*), tidewater goby (*Eucyclogobius newberryi*), delta smelt (*Hypomesus transpacificus*), Chinook salmon (*Onchorhynchus tschawytscha*), and steelhead (*Oncorhynchus mykiss irideus*). By incorporating the recovery needs of these species in the ecosystem restoration designs of this draft recovery plan, they are expected to benefit from *tidal marsh* recovery implementation rather than suffer indirect adverse impacts.

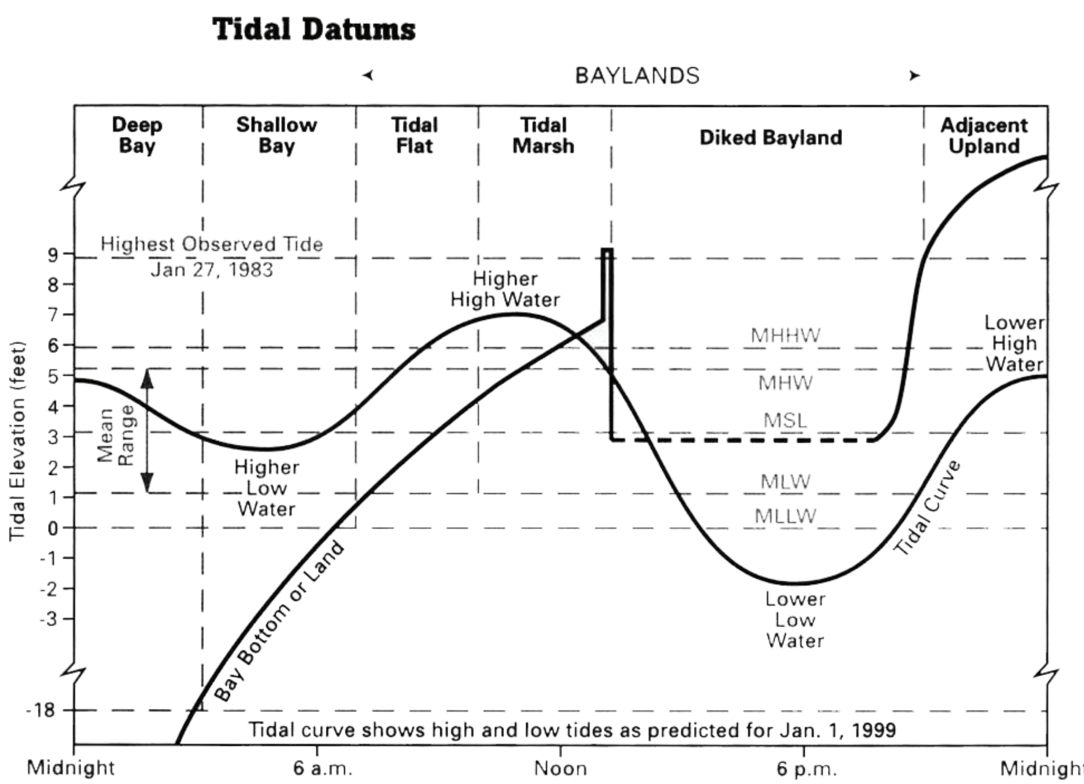
Recovery actions directed at *tidal marsh* ecosystems may also affect other species that are established in habitats in the modern San Francisco Bay Estuary that are related to, but distinct from, *tidal* marshes, such as shallow *lagoons*, *salt pans*, many types of *diked* baylands, *tidal riparian* habitat, and inter*tidal*flats. These associated wetlands provide ecologically important habitat for migratory shorebirds and waterfowl, and federally listed western snowy plovers and California least terns. Many species that depend on wetland types other than *tidal marsh* in California estuaries would be affected by restoration of *tidal marsh* to recover endangered species. These include rare *endemic* insects, resident (nonmigratory) shorebirds, wading birds, perching birds, and raptors. A major objective of the draft recovery plan is to remedy the historical and ongoing causes of degradation or loss of both *tidal marsh* ecosystems and associated estuarine wetland habitats. Our intent is to facilitate use of recovery strategies that prevent avoidable conflicts of estuarine resource management, and that generate sustainable conditions for recovery of endangered *tidal marsh* species and their ecosystems. A list of common and scientific names of species covered in this draft recovery plan is provided in **Appendix A**.

b. Tidal Marsh Ecosystems of Northern and Central California

Three groups of *tidal* salt *marsh* communities are recognized in California: southern, central, and northern (MacDonald and Barbour 1974, MacDonald 1977, Peinado *et al*. 1994). The southern California *tidal* marshes are ecologically similar to *tidal* marshes of Baja California (MacDonald and Barbour 1974). Point Conception (Santa Barbara County) is a major geographic boundary for many *tidal marsh* species with subtropical affinities, such as the endangered light-footed clapper rail (*Rallus longirostrus levipes*), *Monanthochloë littoralis* (shoregrass), and *Batis maritima* (saltwort). The vegetation dynamics of many southern California *tidal* marshes appear to be distinct from those north of Point Conception, marked by strong influences from hyper*salinity*, pulses of coarse river *sediment* deposition, and episodic constriction of *tidal inlets* and flows (MacDonald and Barbour 1974, Zedler *et al*. 1986, Callaway *et al*. 1990). Characteristic species of southern Californian *tidal* marshes have their northern limits at either Morro Bay—such as *Cordylanthus maritimus* ssp. *maritimus* and *Atriplex watsonii* (Watson's saltbush)—or south of Point Conception, such as *Astragalus pycnostachyus* var. *lanossisimus* (Ventura Marsh milkvetch) and *Suaeda esteroa and S. taxifolia* (*estuary* and wooly sea-blites).

Central and northern California estuaries are linked by numerous rare species that require *tidal* salt and *brackish marsh* habitats, such as the endangered California clapper rail. Other rare state, or federally listed *tidal marsh* species include *Suaeda californica* and *Cordylanthus maritimus* ssp. *palustris* (Point Reyes bird's beak). Salt *marsh endemic* species include *Castilleja ambigua* ssp. *humboldtiensi* (Humboldt Bay owl's clover) and *Astragalus pyncnostachyus* var. *pycnostachyus* (coast milk-vetch).

The ecological boundaries of *tidal marsh* ecosystems are elastic; they change depending on the specific component species and the physical processes of the environment. Important physical factors influencing *tidal marsh* ecosystems include the *tides* and elevation relative to the *tides*, *salinity* versus *freshwater* inputs, sedimentation, waves and erosional energy, and soil factors, such as soil *salinity*, aeration, and chemical reduction-oxidation (redox) potential. *Tides* follow a well-marked lunar cycle (see **Figure I-3**), and also are shaped by local geography. Many other physical factors are closely interrelated with *tides* and each other. For example, soil *salinity* is influenced by water *salinity*, frequency of *tidal*inundation, evaporation, drainage, and other factors. Even elevation, which would seem primarily derived from geology, is affected by erosional and depositional forces as well as the role of vegetation in trapping *sediment* and building elevation.



This schematic diagram shows tidal datums for a mixed tide for the major baylands and adjacent habitats. The tidal curve and datums represent the Golden Gate. Bay bottom and land elevations are much more variable than shown. The mean range of the tide also varies around the Estuary.

FIGURE I-3. Tidal datums (reprinted from Goals Project 1999)

Tidal marsh ecosystems can be affected by landscapes and processes distant from the *marsh*. For example, the San Francisco Bay Estuary is the downstream end of the entire Sacramento-San Joaquin watershed, which has profound control over the *estuary's hydrology* and *salinity*.

The steep California outer coastline provides relatively few settings where *tidal*marshes can develop. *Tidal marsh* systems in California are principally found in sheltered shallow *embayments* (*lagoons*, esteros, harbors, bays), *barrier beach* systems, and drowned river valleys with relatively stable or persistent *tidal inlets*. Modern California *tidal* marshes formed near their current locations in response to sea level rise following deglaciation (Atwater 1979). The San Francisco Bay Estuary contains by far the largest *tidal marsh* ecosystem in California today, but the distribution and viability of many *endemic* salt *marsh* species depends on smaller marshes along the coast.

The seven major *tidal marsh* systems of the central and northern California coast covered in this draft recovery plan are Humboldt Bay, Bodega Bay, Tomales Bay, Bolinas Lagoon, the San Francisco Bay Estuary, Elkhorn Slough, and Morro Bay. These and related smaller, but ecologically important, *tidal marsh* systems are briefly described below.

B. San Francisco Bay Estuary tidal marshes

The San Francisco Bay Estuary here refers to the saline *tidal* waters and wetlands between the Golden Gate Bridge and the mouths of the Sacramento and San Joaquin rivers near Antioch. It is also known as the San Francisco Estuary (Goals Project 1999) and the Sacramento-San Joaquin River Estuary. It includes San Francisco Bay, Richardson Bay, San Pablo Bay (including Petaluma Marsh, Napa-Sonoma Marshes), Carquinez and Mare Island straits, Suisun Bay, Honker Bay, Grizzly Bay, Suisun Marsh, and the lower Sacramento/San Joaquin River to Browns Island. For convenience, the bays, straits, and marshlands on the Contra Costa and Solano County shores around Suisun Bay are collectively treated as the Suisun Bay area.

The San Francisco Bay Estuary contains the largest expanses of *tidal*marshes in California. The size and ecological characteristics of the *tidal marsh* of the *estuary* varied in post-*glacial* times (Atwater 1979, Byrne *et al*. 2001). The early 19th century *tidal marsh*, before substantial human impact, is estimated to have been approximately 190,000 acres (Goals Project 1999). Today, only about 40,000 acres of *tidal marsh* remain, much of which occurs along the bayward fringes of *dikes* along the former edges of large *tidal* channels or *mudflats*. *Mudflats* are an extensive component of the inter*tidal* zone of the San Francisco Bay Estuary today.

a. Pre-historical and early historical tidal marsh

Extensive ecosystem changes from the pre-historical and early historical ecological conditions of the San Francisco Bay Estuary have caused the decline of many *tidal marsh* species. Conditions of the pre-historical *estuary* also provide important information on habitat features and processes that need to be restored or replaced to recover endangered species.

The predecessors of modern *tidal* marshes probably were distributed along the now-submerged coastal shelf during periods of lower sea level during the late *Pleistocene* and early *Holocene* epochs. Much as today, these marshes probably were associated with river deltas, estuaries, and *tidal inlets* along former coastal plains many miles west of the modern coastline.

The San Francisco Bay Estuary, like all others in California, formed in relatively recent geologic times (10,000 to 6,000 years ago) as a result of rising sea level following the melting of continental glaciers. The Golden Gate, a stream-cut valley during *glacial* low sea level, became the mouth of the *estuary*. *Tidal* marshes formed along shallow margins of the *estuary* where *sediments* from major stream systems and the Sacramento-San Joaquin Rivers accumulated (Atwater 1979, Atwater *et al*. 1979).

Tidal marshes of the San Francisco and San Pablo bays in early historical times consisted of systems of highly sinuous hierarchical dendritic *tidal* creek networks and complexes of *salt pans* in a matrix of extensive continuous *marsh* plain. The structure of many of these early historical *tidal* marshes is recorded in detailed topographic maps produced by the U.S. Coast Survey (Grossinger 1995).

In the 19th century, Suisun Marsh consisted of extensive *brackish marsh* plains and *tidal* creeks affected by the *salinity* fluctuations of the mixing zone of the Sacramento/San Joaquin delta (Conomos 1979, Peterson *et al*. 1989. Grewell *et al*. 1999). The extensive *marsh* plains were dominated by *Distichlis spicata* (saltgrass) assemblages, consisting of *Distichlis spicata*, *Sarcocornia pacifica* (pickleweed), rush (*Juncus* spp.), bulrush (*Scirpus* spp.) or sedge vegetation (*Scirpus* spp.) in more *brackish* conditions (George *et al*. 1965, Wells 1995, Byrne *et al*. 2001).

Habitat variation of early historical *tidal* marshes was formerly much higher than today, as indicated by the richness and diversity of vascular plant species (Brewer *et al*. 1880, Greene 1891, 1894; Brandegee 1892, Jepson 1911, Howell 1949, Thomas 1961). Many historical *tidal marsh* species were indicators of *ecotones*. Important *ecotones* in and around *tidal marsh* include *brackish* marshes and *marsh* edges (indicators of local *freshwater* drainage and subsurface flows), sandy or shell-hash *marsh* beaches and *spits*, winter-ponded *subsaline* or *alkaline tidal marsh* borders of lowland grasslands, and *alluvial fans* and small deltas grading into *tidal marsh*. Early historical records and accounts also indicate that wildlife species abundance in *tidal* marshes was far greater only a century ago (Zucca 1954; Meiorin *et al*. 1991; Goals Project 1999, 2000)

Soils. The *marsh* substrate in the western part of the *estuary* is mostly bay mud (“Reyes” soil series), silty clays, and clayey *silts*, with peaty organic matter accumulation in the upper *marsh* soil profile. Deep organic muck and peaty soils (“Joice” and other typical soil series) occur in the *brackish tidal* marshes of the Suisun Marsh area (U.S. Department of Agriculture 1977). Sands are relatively localized in San Francisco Bay *tidal marsh* soils today, unlike maritime California *tidal* marshes.

Remaining marshes. While most original pre-historical marshes have been destroyed or altered, one large expanse of pre-historical *tidal brackish marsh* has been preserved (Petaluma Marsh), and numerous smaller *marsh* remnants persist. These remnant pre-historical marshes are not only critically important refuges for *populations* of rare species, but they contain invaluable and irreplaceable information, preserving clues of the origin, development, structure, and composition of natural *tidal marsh* systems over several thousand years. Other important examples of remnant pre-historical *tidal* marshes in the San Francisco Bay Estuary include portions of Newark Slough, Bird Island, and Greco Island (South Bay); China Camp, Fagan Marsh, and Whittell Marsh (North Bay); and the Hill Slough-Rush Ranch area (Suisun Marsh).

Tidal marsh pans. Tidal marsh pans (or pannes) are shallow pools or seasonally drying flats in poorly drained areas of *marsh* plains. They were formerly much more common and extensive, occurring between *tidal* creeks, often toward the landward edge of the *marsh*. Large *pans* also occurred where wave-built *berms* or natural creek *levees* obstructed *tidal* drainage (Atwater *et al*. 1979), and in areas with relatively pronounced influence of stream discharges (Grossinger 1995). In general, these *pans* would have *tidal* exchange at least during extreme high *tides*.

Upland habitat. The interspersion of *uplands* and *tidal marsh* habitats in pre-historical estuarine conditions was significantly different from the modern *estuary*. Although some parts of the *estuary* had relatively steep upland slopes and sharply demarcated *tidal marsh* edges, much of the *estuary* edge occurred along floodplain valleys and *alluvial fans*, with very gradual slopes and *ecotones*. Beyond these *ecotones* were vast, deep (from shore to bay), extensively contiguous *tidal*marshes separated by large distances from *uplands*. Although natural *levees* along large *sloughs* provided emergent habitats above normal *tides*, these did not provide *refugia* for predator nests or dens, because they were submerged in spring *tides* and *storm surges*. *Tidal marsh* "islands" were common, separated from each other and the mainland by a network of *tidal*creeks. Native terrestrial predators, such as foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*), were restricted to contacts along upland and alluvial margins. Terrestrial predator access to deep (from shore to bay), extensive *tidal*marshes and *marsh islands* was limited by long distances from secure, unflooded terrestrial nest and denning sites. Large *tidal*creeks, wide *salt pans*, and distance from *uplands* probably provided substantial barriers to dispersal of terrestrial predators in *tidal marsh* ecosystems.

Unlike terrestrial-salt *marsh ecotones* along the *marsh* edge, creek bank *levees* were extensively distributed throughout the *marsh*, providing well-dispersed emergent *marsh* and tall vegetation during extreme high *tides* (Johnston 1957), providing important protection from predators. The diking of major *sloughs* destroyed natural *levee* habitats on both sides of the *dikes* via flooding. Adjacent *undiked sloughs* filled with *sediment* and sloping young *marsh*, eliminating natural *levee*-forming processes.

Barrier beaches and sand spits. Important exceptions to the lack of true terrestrial habitats within early historical *tidal* marshes were *barrier beach* and sand spit habitats, which were formerly widespread around salt marshes of the central portions of San Francisco Bay. A *barrier beach* is a *beach ridge* that encloses and shelters a *lagoon*, *tidal* flat, or *backbarrier marsh*. *Barrier beaches* attached at one end, usually near the sand source, are called *spits*. *Barrier beaches*, *beach ridges*, and sand *spits* formed *ecotones* between *tidal marsh* and sand dunes. Beaches and *spits* along salt marshes (*e.g.,* Alameda, Bay Farm Island) were probably important high *tidal* flood *refugia* for many wildlife species, provided unvegetated high *tide* shorebird roosts on unstable *beach ridges*, and created well-drained high *marsh* habitat for salt *marsh* plants that have become rare or extinct regionally (*e.g., Suaeda californica, Atriplex californica*).

Sandy estuarine *barrier beaches* were concentrated around the central Bay. They were common in Richardson Bay, the northern San Francisco peninsula, and were particularly well-developed in the East Bay from Richmond to Alameda. Beaches tended to cluster around erodible sand sources, such as the *Pleistocene* Merritt (East Bay) and Colma/Merced (San Francisco peninsula) geologic formations (Louderback 1951). *Barrier beaches* often enclosed *lagoons* or sheltered *tidal* marshes. The San Francisco Estuary Institute (1998) estimated that over 37 kilometers (23 miles) of sand beach shoreline, both fringing and *barrier beaches* 12 to 18 meters (40 to 60 feet) wide, existed in San Francisco Bay alone before 1850 (Goals Project 1999, R. Grossinger pers. comm. 2000).

There are few *barrier beaches* or sand *spits* left in the San Francisco Bay Estuary. The extensive sand *spits* of the Berkeley-Oakland shoreline were largely destroyed by urbanization by 1880. One significant sand spit has re-formed at the bayward edge of salt marshes near the mouth of San Lorenzo Creek (Alameda County) where it grew large enough to develop low dunes and *washover* fans (P. Baye pers. observ. 1991-2002). Another narrow spit has retreated along with the edge of Whittell Marsh, Point Pinole. Relatively small and short-lived shell *spits* and *beach ridges* are scattered around Brisbane, Foster City, Bird Island, Bair Island, and Ravenswood in San Francisco Bay.

Lagoons. Natural *impoundment* of local *freshwater* drainages, for example by *barrier beaches*, created *lagoons*, which were probably intermittently *tidal* and *brackish* depending on *tides* and flood events. Natural *lagoon* habitats have been almost entirely eliminated from the San Francisco Bay Estuary, although examples remain along the outer coast. Morro Bay is an example of a large *barrier beach* with a persistently open channel to the ocean, thus its title of "bay" rather than "*lagoon*." One small example of a *backbarrier lagoon* occurs in a natural *tidal marsh* and narrow sand beach near Point Pinole today.

Salt ponds. Vegetated sandy *marsh berms* (*e.g., beach ridges*), or similar features made of *sediments* other than sand (*e.g. shell hash*), were probably important to the natural impoundment of Crystal Salt Pond, an area of drowned *marsh* near present-day Hayward (Alameda County) that functioned as a natural salt crystallizing *pan* (Atwater *et al*. 1979). A cluster of similar salt ponds extended from what is now southern Oakland to the San Lorenzo Creek area. Little is known of the original condition of these natural salt ponds because they were modified as early as 1853 to become the forerunners of the industrial solar salt industry (Ver Planck 1958). They supported thick beds of halite (up to 20 centimeters [8 inches] of crystalline salt) (Ver Planck 1958), unlike typical *tidal marsh pans*, and were exploited by local Native Americans. The ecological attributes of these salt ponds are inferred by comparison with industrial salt ponds (Baye *et al*. 1999), but were not documented by early naturalists or scientists before they were converted to highly managed artificial systems. They have been entirely eliminated in their natural state.

Berms. Natural bay/*marsh* edge *berms* along northern and eastern San Pablo Bay became the foundations for Highway 37 and the original *dike* alignments for the Novato (Marin County) Hamilton/Ignacio *dikes*. Natural bay/*marsh* edge *levees* have partially reformed in the prograded *marsh* plain south of Highway 37.

Vernal pool/grasslands. One of the most significant types of *tidal marsh ecotone*, of which only vestiges remain today, was extensive lowland *alkaline*/*subsaline* grassland with complexes of *vernal pools*, *vernal swales*, and marshes. *Tidal marsh* edges along alluvial grasslands with clayey soils apparently developed wetland types intermediate between *vernal pools* and *brackish salt pans*. The vegetation that occurs in this *ecotone* includes a number of species that occur in both salt *marsh* edges and *subsaline*/*alkaline vernal pools* of valley grasslands, such as *Downingia pulchella* (flatface downingia), *Astragalus tener* var. *tener* (alkali milk-vetch), *Eryngium armatum* and *E. aristulatum* (coyote-thistles), *Castilleja ambigua* (johnny-nip or salt *marsh* owl's-clover), *Lepidium latipes* (peppergrass), and others. *Vernal pool*/salt *marsh* indicator species were reported from localities where *vernal pools* and *tidal* marshes apparently formed *ecotones* (Jepson 1911). The derelict pasturelands in the Warm Springs area near Fremont (Alameda County) are surviving representatives of this former *ecotone*.

Other *vernal pool*-bearing grasslands formerly graded into *brackish tidal*marshes in the Petaluma, Sonoma, and Napa valleys, and the Suisun-Fairfield-Denverton area, with remnant grasslands persisting today near Denverton, Potrero Hills, and lower Sonoma Valley (Goals Project 1999). Salt *marsh*/*vernal pool ecotones* in valley lowlands fringing the bay from Hayward to Redwood City were formerly prevalent (from herbarium collection data, habitat and distribution descriptions from older regional floras, and historical descriptive accounts, including by J.B. Davy; R. Grossinger pers. comm. 2000), including many *vernal pool*/salt *marsh* "dualist" species, which have adapted to both habitats. The federally endangered *Lasthenia conjugens* (Contra Costa goldfields) is one example. Today, no intact examples of intermediates between *brackish tidal marsh* edge *pans* and *vernal pools* exist because *tides* are generally excluded from low-lying areas adjacent to San Francisco Bay.

b. Historical tidal marsh loss and degradation around the San Francisco Bay Estuary

Major alteration of the San Francisco Bay Estuary *tidal* marshes occurred during and after the California Gold Rush. The principal causes of *tidal marsh* loss were diking for agricultural conversion of tidelands in the North Bay and solar salt production (and some failed agriculture) in the South Bay (Nichols *et al*. 1986). Conversion of tidelands was accomplished by construction of mud *levees* along the edges of *marsh* plains, and damming of smaller *tidal* creeks (Ver Planck 1958). In addition, roughly 50,000 acres of *tidal marsh* were filled to allow urban or commercial development (Goals Project 1999).

By the early 20th century, most of San Pablo Bay and Suisun Bay *tidal* marshes had been *diked* for agriculture (Meiorin *et al*. 1991). Partial failure of *dikes* or drainage systems caused some agricultural baylands to revert to wetland conditions. This facilitated the conversion of many parcels to managed waterfowl marshes in Suisun Marsh and solar salt ponds in eastern San Pablo Bay.

By 1989, the total area of *tidal marsh* in the *estuary* was estimated to have declined to between 12,140 hectares (30,000 acres; Dedrick 1989) and 16,187 hectares (40,000 acres; Goals Project 1999). At a minimum, estimates indicate a loss of 79 percent of *tidal marsh* habitat area since the 1800s, and only 8 percent of the original pre-historical *tidal* marshes remain (Goals Project 1999). The habitat structure and quality of modern marshes differ from their pre-historical antecedents. Thus, the ecological impact of *tidal marsh* loss exceeds the minimum 79 percent loss.

Agricultural alteration of former *tidal* areas continues around the *estuary*. Around San Pablo Bay, for example, replacement of low-intensity agriculture (pasture and oat hayfields) with intensive agriculture (vineyards) is occurring, and threatens to preclude *tidal marsh* restoration over significant areas where restoration is otherwise highly feasible.

Managed salt ponds. Managed salt ponds are shallow open water habitats with no *tidal* flow. These wetlands contain water all year long and can have various salinities, from low *salinity* (similar to seawater) to high *salinity* (3 times seawater *salinity* or more). The ponds can vary in depth from very shallow (less than 12 inches) to more than 3 feet. The solar salt industry began building managed salt ponds in the San Lorenzo area in San Francisco Bay in the mid-1850s. The 1920s and 1930s witnessed the end of extensive *tidal* marshes in the South Bay due to their replacement by the rapidly expanding salt industry (Ver Planck 1958). Managed salt ponds occupied more than 11,000 hectares (27,000 acres) in former *tidal marsh* in south San Francisco Bay. The last extensive *tidal* marshes of the South Bay, between Sunnyvale and Milpitas, were *diked* in the early 1950s (U.S. Army Corps of Engineers, San Francisco District, permit file information). Some salt pond *dike* failures in the early 20th century resulted in reversion to *tidal* salt *marsh*, which are relatively mature habitats today (*e.g.,* Whale's Tail Marsh, Ideal Marsh, near Hayward).

The modern industrial salt pond system has been in place since the 1950s. Internal changes within the system occurred when the caustic magnesia industry left the region, causing bittern (salts of magnesium and potassium), a by-product of salt production, to accumulate as a waste product. When bay discharges of bittern became prohibited by law, toxic bittern was stored in former salt evaporation ponds for decades, covering hundreds of acres adjacent to *tidal* salt *marsh*.

Diked wetlands. Diked wetlands, such as swales in farmed baylands or managed non-*tidal* waterfowl marshes in Suisun Marsh, provide surrogate habitat for species that historically used habitats within *tidal* marshes, particularly shorebirds, wading birds, waterfowl, and salt *marsh* harvest mice. These are, however, unstable artificial wetlands. In addition to long-term constraints on sustainability and costs of *dike* maintenance, these baylands are subject to progressive *subsidence* and related problems, such as decreasing drainage efficiency, salt accumulation, and potential for *catastrophic* flooding. *Subsidence* problems (depression of ground surface elevation below sea level) in *diked* baylands are due primarily to (1) aerobic microbial decomposition of organic matter in former *marsh* soils, (2) cessation of *tidal* sedimentation, and (3) rising sea level. The longer *marsh* soils are kept drained, the more soil organic matter may be lost, and the deeper they may subside. The more organic matter in the soil, the greater the potential for *subsidence*. For these reasons, the *diked* baylands in Suisun Marsh, with deep organic soils, are subject to particularly deep *subsidence*. As *diked* baylands subside below sea level, they become increasingly difficult to drain through flapgates at low *tide*. Adverse soil conditions, such as local accumulation of soluble iron salts, sulfides, and sodium salts, develop in undrained depressions. As *diked* baylands subside further and sea level continues to rise, the risk of *levee* failure and prolonged deep flooding increases.

Extensive diking of *tidal* marshes and smaller *tidal* creeks results in reduced *tidal prism* (total volume of *tidal* flows), which increases sedimentation in *slough* beds and *mudflats*. The combined effects of *tidal prism* loss and massive discharges of *sediments* from hydraulic gold mining in the Sierra Nevada caused large-scale deposition of inter*tidal mudflats* and rapid growth of fringing *tidal* marshes in San Pablo Bay (Atwater *et al.* 1979). This growth partially offset some of the initial massive losses of *tidal marsh* area caused by conversion, but new marshes were structurally unlike the original *tidal* marshes. New marshes formed on sloping *mudflats* drained by relatively straight, narrow channels and lacked the sinuous dendritic creeks and complex topography of pre-historical marshes. Unlike the gentle or variable gradients from *marsh* to upland of the pre-historical *tidal marsh ecotones*, recently formed marshes often have abrupt, steep contacts with *dikes* or *levees*. This artificially narrow high *marsh* zone resulted in a profound decline in the availability and distribution of ecotonal habitat as well as high *tide* cover for wildlife (Shellhammer pers. comm. 2005).

Diking of *tidal* marshes resulted in fragmentation of wetland habitats around the *estuary*. *Dikes* and habitat destruction or alteration in areas surrounded by them created barriers between remaining *tidal marsh* habitats and *populations*. Normal channels of water and *sediment* movement were cut off. *Dikes* themselves occupy considerable area, and destroyed or drastically altered the habitat around them.

Predation. The pervasive system of *dikes* in the modern San Francisco Bay Estuary has changed the way terrestrial predators move in *tidal* marshes. Marshes today are linked by a network of upland dispersal *corridors* provided by *dikes*. Most remnant or recent *tidal marsh* area now lies within a few hundred meters (less than 1/4 mile) from upland *dikes*. *Dikes* also provide nesting and denning sites for both native and *non-native* predators, allowing them to expand their foraging into otherwise inaccessible *tidal* marshes. This structural change of modern *tidal* marshes is the core of modern predation problems for native *marsh* wildlife today.

In addition, power transmission and distribution towers provide nesting habitat for red-tailed hawks (*Buteo jamaicensis*) and common ravens (*Corvus corax*) which predate California clapper rails, as well as provide perching opportunities for a variety of avian predators. Boardwalks provide access through marshes for terrestrial predators and humans, as well as avian perches.

Fill. Extensive fill of *tidal marsh* and *mudflat* for urbanization beginning in the 19th century was another major cause of salt *marsh* losses in the San Francisco Bay, notably in the urban *corridor* from Richmond to Alameda and on the San Francisco peninsula. Expansion of airports, shipping ports, industry, commercial and suburban residential development, and landfills spread into many square miles of *diked* baylands, *tidal* marshes, and *mudflats* through the 1960s (Nichols *et al*. 1986, Meiorin *et al*. 1991). Unlike *diked* baylands in agricultural or solar salt production, this urban and suburban sprawl caused essentially irreversible habitat destruction. Fill of *tidal* wetlands decreased significantly between the 1980s and today with increased enforcement of new Federal and State environmental regulations (*e.g.*, Clean Water Act). Still, extensive fill of restorable *diked* baylands has continued (*e.g.,* Redwood City, Black Point, Fremont Airport projects), and further extensive fills are still pending (Bahia, St. Vincent's/Silvera [Marin County]).

Other changes. Other major changes in California *tidal marsh* conditions in the last two centuries have included rising sea level, alteration of *freshwater* flows due to dams and diversions, the introduction of many *non-native* species, and exposure of *tidal* marshes to a variety of chemical contaminants. These changes are discussed in greater detail in the Threats to California Tidal Marsh Ecosystems section, below.

c. Tidal marsh habitats of the San Francisco Bay Estuary

Healthy intact *tidal marsh* ecosystems include a variety of habitats, generally stratified in zones depending on their elevation in relation to the reach of the *tides* (Hinde 1954; Atwater and Hedel 1976, Peinado *et al*. 1994). Some of these habitats, or particular variations within them, have been mentioned above, such as *tidal marsh pans*, *barrier beaches*, and natural *berms*. A diversity of habitat types is often beneficial to wildlife, especially where it provides a range of habitats useful in feeding, breeding, or sheltering. Even for plants, which live most of their life cycle fixed in place, habitat diversity can be important in providing habitats for pollinators or controlling environmental factors such as erosion or drainage.

Low marsh. Low marshes, those below Mean High Water (MHW; see **Figure I-1**), usually occur in narrow bands along *tidal* channel banks and *mudflat* edges, providing habitat for inundation-tolerant grasses or grasslike vegetation: *Spartina foliosa* (California cordgrass) in salt *marsh*, *Scirpus* species (bulrushes and tules), and *Typha* species (cattails) in *brackish* marshes. *Salinity* is one factor in preventing other plants from growing here, and lack of drainage and associated soil conditions preclude other *halophytic* plants. At the lowest elevations, low *marsh* vegetation is inhibited by frequent, prolonged, often deep inundation and disturbance by waves or currents. Significant areas of *marsh* establishment and *accretion* (build up) over *mudflats* still occur in parts of the South Bay (Mowry and Dumbarton Marshes, Calaveras Point to Coyote Creek) and portions of San Pablo Bay (Doane 1999). Once vegetation is established, it often can trap and accrete *sediments* and plant litter, gradually building *marsh* elevation in opposition to forces of erosion, and may eventually build high enough to put the habitat into a higher *marsh* zone.

Middle marsh. Broad, nearly flat *tidal marsh* plains typically represent the middle *marsh* zone, dominated mostly by low herbaceous and weakly woody species, often with creeping growth habits. Middle *marsh* usually is found between MHW and Mean Higher High Water (MHHW). This zone is typically dominated by *Sarcocornia pacifica* (pickleweed) and sometimes also *Cuscuta* spp. (dodder; Howell 1949) in young/developing marshes, but consists of variable mosaics of *Sarcocornia pacifica, Cuscuta salina* (salt marsh dodder), *Jaumea carnosa, Distichlis spicata* (saltgrass) and *Frankenia salina* (alkali-heath) in established salt marshes. While *Sarcocornia* and other plants here provide food for wildlife, there is relatively little cover and no refuge from higher *tides*, which completely flood the typical vegetation of the middle *marsh*. Besides elevation relative to the *tides*, *marsh* vegetation also is affected by drainage so that higher areas with poor drainage may have vegetation more characteristic of lower elevations.

High marsh. High *tidal marsh* zones (also known as upper *marsh*) generally occur above MHHW to the limit of influence of spring *tides* or *storm surges*. In the San Francisco Bay Estuary high *marsh* now is often confined to natural *levees* along *tidal* creek banks and edges of artificial *dikes*. High *marsh* typically occurs along elevated or better-drained *sediment* deposits associated with major creek banks, *alluvial fans*, stream mouths, and gradients to terrestrial soils. This zone may be dominated by a variety of plant species with higher plant species richness and intraspecies variability than the lower zones. It is also subject to invasion by many *non-native* plant species in the Bay area. High *marsh* often includes a *driftline* zone or *wrack* line of *tidal* litter, debris that can smother *marsh* vegetation locally and open vegetation gaps. The moist undersides of *driftlines* provide important microhabitats for invertebrates and are preferred salt marsh wandering shrew habitat (Albertson *in litt*. 2009*a*).

High *tidal marsh* often is dominated by a variable association of *Grindelia stricta var. angustifolia* (*marsh* gumplant), *Distichlis spicata*, *Sarcocornia pacifica*, *Frankenia salina*, but includes many other species that have declined or are regionally rare in *tidal* marshes. In the eastern part of the *estuary*, *Cressa truxillensis* (alkali-weed) is common in the high *marsh* zone. High *tidal marsh* with lower soil *salinity* also includes *Baccharis douglasii* (marsh baccharis) and *B. pilularis* (coyote brush), *Scrophularia californica* (California figwort), *Leymus triticoides* (creeping wildrye), *Rosa californica* (California rose), and *annual* salt-tolerant herbs. High *marsh* at the landward edge can also intergrade with *freshwater marsh* (cattail/bulrush/sedge *marsh*) or *riparian* thickets (willow/blackberry vegetation).

Improved drainage often facilitates the dense growth of taller forms of high salt *marsh* vegetation, such as *Grindelia stricta* var. *angustifolia* and tall erect forms of *Sarcocornia pacifica*. This effectively raises the height of *marsh* plant stems well above the locally elevated *marsh* surface, adding a canopy 0.3 to 1.0 meter (about one to three feet) above the high *marsh*. This high *marsh* canopy may remain emergent above even the highest storm *tides*, providing well-distributed high *tide* cover (*tidal refugia*) for *marsh* wildlife. In fact, *Frankenia salina* (alkali-heath), *Jaumea carnosa* (fleshy jaumea) and *Distichlis spicata* (salt grass) in this zone have been observed to be teeming with rodents during high *tide* events (Albertson *in litt.* 2009*a*). High *marsh* vegetation along *tidal* creek networks can trap debris in the *marsh* during extreme *tides*, providing additional important cover for wildlife (Johnston 1957).

Brackish tidal marsh. Regionally, *brackish marsh* refers to vegetation that develops under fluctuating mixed salt and *freshwater* influence. It is not precisely defined by *salinity* range, but has been defined as *marsh* with a *salinity* range of approximately 3 to 15 parts per thousand (National Wetlands Research Center 2007). *Brackish marsh* vegetation prevails in the vicinity of river and creek discharges, for example, in the Petaluma Marsh, Napa-Sonoma Marshes, and Suisun Marsh and Bay (Baye *et al*. 2000).

Tidal brackish marsh vegetation in the San Francisco Bay Estuary is distinguished from salt *marsh* by several factors, particularly the structure and composition of low *marsh* and middle *marsh* vegetation. Low *brackish marsh* is dominated by *Scirpus maritimus* (alkali-bulrush), *Scirpus acutus* (hardstem tule), *Scirpus californicus* (California tule), and *Typha* spp. (cattails). *Spartina* is a significant component of low *brackish tidal marsh* only west of Grizzly Bay. Middle *marsh* plains in *brackish* marshes vary in composition more than in salt marshes, and in years of high runoff include significant abundance of bulrushes (*Scirpus americanus* in Suisun area, *S. maritimus* in south San Francisco Bay and north San Pablo Bay), rushes (*Juncus balticus*, *J. lesueurii* and intermediates), *Triglochin maritima* (sea-arrow grass), and many herbaceous *tidal marsh* plants with relatively low salt tolerance. Species composition and relative abundance of plants in *brackish marsh* plains fluctuate significantly over precipitation cycles, and vary across *salinity gradients* along *tidal* reaches of rivers and creeks (Grossinger 1995, Baye *et al*. 2000, Byrne *et al*. 2001).

The highest plant species diversity is usually found in the high *marsh* zone in both salt and *brackish tidal* marshes (the upper *marsh* edge and higher creek *berms* or natural *levees*) . The distinction between *brackish* and salt *marsh* is weakest in the high *marsh* zone because salt influence can be locally elevated by evaporation or depressed by surface drainage or groundwater discharge. As a result, there is considerable variability and overlap in plant species of high *brackish* and high salt *marsh*.

The Pacific Flyway

Tidal marsh and pond habitat along the coast of California is vital to migratory birds as they travel between their nesting grounds in the north and their wintering grounds in the south. The Pacific Flyway, one of four major routes in North America, is a bird migration pathway that generally runs from Alaska and the Aleutian Islands south to Mexico and South America, paralleling the coast of Washington, Oregon, and California. Other routes of the Pacific Flyway pass further inland. A network of wetlands along the flyway serve as critical resting and refueling stops for large *populations* of shorebirds and waterfowl. Important habitats for the migrating and wintering waterbirds include *tidal* flats, managed wetlands, large persistent seasonal ponds, and active and inactive salt evaporation ponds (Goals Project 1999). Migrating land birds benefit from higher *marsh* habitats and *riparian* and upland transition habitats.

The San Francisco Bay Estuary is the largest *estuary* on the west coast of the U.S. and one of the most important staging and wintering areas for migratory waterfowl in the Pacific Flyway. It has been designated a Western Hemisphere Shorebird Reserve Network site of international importance. During the height of migration, up to 1,000,000 shorebirds can be counted in the spring, and up to 375,000 in the autumn (Page *et al.* 1989). At least 34 species occur regularly in the *estuary*. San Francisco Bay is the winter home for more than 50 percent of the diving ducks in the Pacific Flyway with one of the largest wintering *populations* of canvasbacks (*Aytha valisineria*) in North America (Goals Project 1999). Seventy percent of the birds that migrate along the Pacific Flyway spend some time each year at the San Francisco Bay.

Migration strategies are complex, with great variation both between and within species (Warnock *et al.* 2002; Greenberg and Marra 2005). Birds travel varying distances and follow different routes. They may stay for varying lengths of time to rest, feed, or overwinter in an area. The primary need of both migrating and wintering birds is food. However, different habitats serve different functions. *Mudflats* at low *tide* provide the primary foraging areas for most waterbirds; seasonal and farmed wetlands may be a secondary foraging area for several species (Harvey *et al.* 1992). Salt ponds provide important roost sites for many shorebirds. In salt ponds during high *tides*, Point Reyes Bird Observatory studies (http://www.prbo.org) indicate that black-bellied plovers and marbled godwits spend almost the entire time roosting, whereas semipalmated plovers, American avocets, willets, dunlins, western sandpipers, least sandpipers, and dowitchers may spend time foraging.

In addition to the San Francisco Bay Estuary, other *tidal marsh* areas along the Northern California coast have been identified as Important Bird Areas (Cooper 2004) including Elkhorn Slough, Bolinas Lagoon, Point Reyes, Tomales Bay, Bodega Harbor, and Humboldt Bay.

Integration of this draft recovery plan with conservation efforts for other species and ecosystems, including recovery plans for other species, such as western snowy plover (U.S. Fish and Wildlife Service 2007*b*) and California least tern (U.S. Fish and Wildlife Service 1985*b*), is discussed in the Recovery Strategies section below, under Ecosystem-level Strategies (III.B.1).

C. Other major tidal marsh ecosystems of the northern and central California coast

a. Humboldt Bay

Humboldt Bay is the second largest *estuary* on the California coast. The bay was historically over 11,000 hectares (27,000 acres) in area, and supported approximately 2800 hectares (7,000 acres) of *tidal* salt *marsh*. Today, fewer than 400 hectares (1000 acres) of salt *marsh* remain (Shapiro and Associates 1980, Barnhart *et al*. 1992). Humboldt Bay is structurally similar to Drake's Estero (Marin County), with drowned river valleys enclosed by asymmetric double barrier *spits* that lack major stream discharges. Jacoby, Freshwater, and Salmon Creeks discharge into the bay, creating local *brackish marsh ecotones*. Most of the *sediment* inputs to Humboldt Bay are derived from offshore, and fed by the diffuse *sediment* plume of the Eel River, which discharges very large volumes of fine *sediment* into the ocean about 15 kilometers (9 miles) south of the Humboldt Bay inlet (Barnhart *et al.* 1992). Humboldt Bay also supports extensive inter*tidal mudflats* (65 to 70 percent of the bay), and *Zostera* (eelgrass) beds (nearly 1200 hectares [3,000 acres; Barnhart *et al.* 1992]). These *mudflats* are higher in *silt* and sand, and lower in very fine *sediments*, than *mudflats* in San Francisco Bay.

The Humboldt Bay *tidal* inlet was stabilized by construction of jetties at the beginning of the 20th century. The artificially open and deep inlet has enabled ocean swells to pass through with greater energy than would propagate through a shallower natural inlet, resulting in salt *marsh* erosion (Barnhart *et al*. 1992).

Most of the historical *tidal* marshes of Humboldt Bay were *diked* for agriculture (primarily cattle pasture) in the 1880s and early 20th century. These low-lying *diked* baylands support seasonally ponded or saturated wetlands and much *non-native* vegetation, as in San Francisco Bay. They also provide important habitat for migratory water birds. Many of the *diked* baylands have subsided below current sea level. There is extensive urban development along portions of the eastern historical baylands.

Early historic *tidal marsh* persists only in remnants, but numerous well-preserved areas occur on Indian Island near Eureka and the Mad River Slough of Arcata Bay (North Bay). Rare *marsh*-to-upland *ecotones* with coastal dunes and *brackish dune slacks*) also occur along the *lagoon* shoreline of the North Spit and South Spit, and along the more recently formed Elk River Spit at the mouth of the Elk River, within Humboldt Bay. North of Humboldt Bay, the Mad River mouth has migrated north in recent decades, creating an enlarged linear stream-mouth *lagoon*, which ranges from fully *tidal* to *microtidal*, with associated vegetation ranging from salt *marsh* to *brackish* and *freshwater marsh*. Extensive *tidal* wetlands also are associated with the Eel River mouth immediately south of south Humboldt Bay.

Humboldt Bay was the site of an early exotic *marsh* plant invasion when *Spartina densiflora* (dense-flowered cordgrass) became naturalized there in the 19th century. It was mistaken for decades as an *ecotype* of *Spartina foliosa* (Spicher 1984). *Spartina densiflora* is now one of the dominant *tidal marsh* species in Humboldt Bay, along with the typical dominant salt *marsh* species of the central coast salt marshes (*Sarcocornia pacifica* and *Distichlis spicata*). It concentrates in the high *marsh* and upper middle *marsh* zones. *Spartina foliosa* (California cordgrass) is not known from Humboldt Bay.

There are several historical reports of California clapper rail from Humboldt Bay (Harris 1996, Gill 1979). The species does not occur there now, and records appear inadequate to determine whether the species formerly bred there in small numbers, or whether those reports that were valid referred to vagrant birds.

Humboldt Bay supports three rare *tidal marsh* plants. The largest *populations* of *Castilleja ambigua* ssp. *humboldtiensis* (Humboldt Bay owl's-clover) still occur in Humboldt Bay *tidal* salt marshes, the *type locality*. Importantly, large *populations* of *Cordylanthus maritimus* ssp. *palustris* (northern salt marsh bird's-beak) also persist there. The rare *Astragalus pycnostachyus* var. *pycnostachyus* (marsh locoweed) formerly occurred in the *barrier beach*/salt *marsh* complex near Samoa at its northern range limit, but has not been reported there in recent years (Andrea Pickart *in litt.* 2009). *Castilleja ambigua* ssp. *humboldtiensis* also occurs at the mouth of the Mad River, and in some agricultural wetlands that are hydrologically influenced by leaking tidegates or *dike* overtopping. *Grindelia stricta* ssp. *blakei* (Humboldt gumplant), now considered taxonomically indistinct from the more widespread *G. stricta* var. *stricta* (Hickman 1993), occurs in local abundance in Humboldt Bay shores and *tidal* marshes.

Humboldt Bay presents a number of challenges to *tidal marsh* recovery. The bay is relatively sediment-starved compared with San Francisco Bay, especially for fine *sediment*. Rapid *tidal* sedimentation may not occur naturally following *tidal*flooding of subsided *diked* baylands in Humboldt Bay. Relatively few *tidal marsh* restoration projects have been implemented there

(Barnhart *et al*. 1992), most by breaching of *dikes*. Some *tidal marsh* restorations, such as the Bracut Marsh near Arcata, have been extensively invaded by the *non-native Spartina densiflora*, and have suffered difficulties in establishing appropriate *marsh* elevations.

Eel River Estuary

Information provided below is from the Lower Eel River Watershed Assessment Report (Downie and Gleason 2007).

The Eel River Estuary, located 15 kilometers (9 miles) south of Humboldt Bay, is the fourth largest *estuary* in California. It is composed of three main areas: the Eel River mainstem, North Bay, and the Salt River. The Eel River Delta encompasses about 130 square kilometers (50 square miles), of which 10 square kilometers (4 square miles) are open *sloughs*, side channels, and *mudflats*. The *tidal* area of the *estuary* has been reduced by an estimated 1,584 hectares (3,913 acres; 60 percent) due to sedimentation and reclamation for agriculture, leaving approximately 560 acres today. Salt *marsh* originally present in the *estuary* has been lost due to diking, filling, and other human activities. *Invasive Spartina densiflora* (dense-flowered cordgrass) has been noted to be widespread in the marshes of the Eel River estuary.

The Eel River was designated as a Critical Coastal Area in 1995, as a waterbody impaired by excessive *sediment* and temperature that flows into an *estuary*. The Eel River has the highest recorded average suspended *sediment* yield of any U.S. river its size, and in 2002, the U.S. Environmental Protection Agency listed the lower portion of the Eel River as an impaired water body due to *sediment* and temperature. A combination of historic and current land use practices, highly erodible soils, and a great deal of seismic activity have resulted in high rates of sedimentation and deposition in the Lower Eel River, which has resulted in:

- An overall decrease in *tidal prism* and shallowing of the *estuary* and riverbed;
- Loss of estuarine habitat area and diversity;
- Loss of spawning area for salmonids due to excess siltation of gravel beds;
- Intermittent and periodically dry reaches in tributaries and lower mainstem Van Duzen River during low summer and autumn flows;
- Highly channelized streams; and
- Reduction of *riparian* vegetation on stream banks.

The Eel River Estuary is home to several species of fish and wildlife, including rare plant and fish species. Currently, there is insufficient information about sensitive plants there, and a complete inventory is recommended.

Tidal marsh restoration is planned for nearly 162 hectares (400 acres) of previously reclaimed lands in the Salt River area. This is part of a larger Salt River Ecosystem Restoration Project that is utilizing upslope erosion control and *riparian* and *tidal* restoration techniques to achieve a dynamic and self-sustaining river system, incorporating low and high *marsh*, mud flat, and *slough* channel habitat.

North Bay is managed primarily by the California Department of Fish and Game as part of their Eel River Wildlife Area. Units within this area are managed for mixed uses including waterfowl hunting, agricultural management for Aleutian goose habitat, and fish and wildlife habitat. Local researchers have been collecting hydrological data on the *tidal* regimes in North Bay to use as a reference for *tidal* restoration projects in Humboldt Bay and the Eel River Estuary.

b. North coast stream mouth estuaries and lagoons

Between the Eel River Estuary and Bodega Harbor (Mendocino and Humboldt counties), coastal rivers and creeks form mouths that are intermediate between estuaries, with persistent *tidal inlets*, and non-*tidal brackish lagoons*, where *beach ridges* allow only storm *overwash* or intermittent *tidal* circulation following storm breaches. These mouths vary in how often *tidal inlets* form, depending on stream discharge, *sediment* supply, storms and waves. Examples of small northern California coast stream-mouth *estuary/lagoons* include the Mattole River, Big River, Navarro River, Garcia River, and Gualala River. Of these, only the Big River mouth typically has a *tidal* inlet, due to the shelter from wave energy of Mendocino Bay. The rest tend to fluctuate between non-*tidal lagoon* conditions in summer and fall, and *tidal* or *fluvial* conditions in the rainy winter-spring months. Accordingly, their wetlands include elements of *freshwater riparian* vegetation, *lagoon* beds (submerged *Ruppia*, emergent *annual* herbaceous vegetation), *brackish tidal marsh*, and *tidal* salt *marsh*. The Big River mouth *estuary* vegetation is unique among these. It supports a small true *tidal* salt and *brackish marsh* system with distinctive *fluvial* topography and channels, and includes narrow *Zostera* beds along channels and salt *marsh* vegetation. The Noyo River mouth is structurally similar, but its floodplains and wetlands have been extensively urbanized. Big Lagoon and Stone Lagoon in Humboldt County are predominantly non-*tidal brackish lagoons*, which breach on an annual basis. Coarse gravel *barrier beaches* are relatively permeable and permit some subsurface exchange of *freshwater* and seawater, as well as infrequent *overwash*. Some *lagoons* intergrade with *brackish* dune wetlands (*dune slacks*) and with intermediate ecotonal vegetation, such as at Manchester State Park, Mendocino County.

These local estuaries, though small, provide significant bridge, or stepping-stone, *populations* for some rare species, and may facilitate range re-expansion of rare species. For example, the Big River Estuary supports an isolated *population* of the rare *Castilleja ambigua* ssp. *humboldtiensis*. These estuaries may have served as staging areas for clapper rails dispersing between San Francisco Bay and Humboldt Bay.

c. Marin-Sonoma coast

The Marin-Sonoma coastline includes many sheltered *embayments* (*lagoons* or esteros) along larger open bays. These *embayments* contain shallow sub*tidal* habitats, extensive sand and mud tideflats, and significant pockets of diverse *tidal marsh* systems. Most *tidal* marshes of the Marin-Sonoma coast are relatively young (Niemi and Hall 1996) compared to the original San Francisco Bay estuarine *marsh* systems (Atwater *et al*. 1979). They consist mostly of pocket salt marshes in partially submerged drainage or fault zones associated with extensive tideflats. The major *tidal marsh* areas of the Marin-Sonoma coast occur at Bolinas Lagoon, Drake's and Limantour Esteros (Point Reyes, south shore), portions of Tomales Bay (mostly creek mouths of the south end and northeast shore), and near Doran Beach and the inlet in Bodega Harbor. Small salt and *brackish* marshes also occur at small *lagoons* and stream mouths with intermittent *inlets* (*e.g.,* Rodeo Lagoon, Estero Americano, Estero San Antonio, Russian River mouth) or without *inlets* (Abbotts Lagoon), usually with limited *tidal* range.

The Marin-Sonoma coast *tidal* marshes have strong maritime influence, with near-marine *salinity* during rainless summers and relatively low suspended *sediment* concentrations compared with San Francisco Bay. *Tidal* flats dominate the inter*tidal* zone of the Marin-Sonoma coast *embayments*. *Brackish* marshes, indicated by *Scirpus maritimus* (alkali-bulrush) stands, occur locally, associated with fresh groundwater emergence and creeks. *Tidal* marshes in these systems are associated with deltas and *alluvial fans* of local drainages, flood *tidal* delta shoals, and *barrier beaches*. Sandy *marsh sediments* are relatively abundant, as are local wave-influenced *marsh* features and patterns. Deposition of fine *sediment* occurs primarily at the sheltered upstream portions of deltaic-patterned *tidal* marshes. These *tidal* marshes typically have relatively smaller, simpler *tidal* creek networks than those of San Francisco Bay *tidal* marshes. Some recently accreting marshes lack *tidal* drainage patterns altogether. *Tidal* marshes in these systems tend to occur in small patches rather than in extensive *marsh* complexes.

Bolinas Lagoon is a *tidal embayment* sheltered by the Stinson Beach spit. Its waters are primarily marine, but 10 small seasonal drainages and the *perennial* Pine Gulch Creek empty into it and establish local *brackish salinity gradients*. The *lagoon*, like Tomales Bay and Bodega Harbor, is associated with crustal movements of the underlying San Andreas Fault. It consists of approximately 405 hectares (1,000 acres) of open shallow water, an emergent flood *tidal* delta island with a thin cap of beach and dune sands (Kent Island), extensive mud and sand *tidal* flats (approximately two-thirds of the *lagoon*), small *alluvial fans* and deltas, and fringing salt *marsh*. The *tidal* flats, channels, and *marsh* fringe of the *backbarrier* shoreline were dredged and filled in the 1960s for a large residential development and marina. Portions of the Pine Gulch delta wetlands were *diked* and converted to agriculture, some of which is still in cultivation. Sedimentation of Bolinas Lagoon during the 19th century has been attributed to past logging and agricultural disturbances in the lagoon's watershed (Giguere 1970), but the relative contribution of *sediments* from marine and local headland origin has not been fully resolved (Rowntree 1973). Although options to reduce sedimentation of the *lagoon*, including dredging, appeared near funding in the mid and late 1990s (Coastal Post Online 2005), a recent study by Gulf of the Farallones National Marine Sanctuary (2008) indicates that the *lagoon's* transition—its loss of depth and the growth of *mudflats*—is natural and progressing toward an equilibrium that won't lead to the loss of the *lagoon* or the need for dredging.

Bolinas *tidal* marshes consist of broad plains dominated by short turf-like vegetation in upper zones, grading to broad *Sarcocornia* zones, *Sarcocornia-Spartina* zones, and pure *Spartina foliosa* (California cordgrass) stands. *Tidal* flats and channels are important habitat for seals, shorebirds, and wading birds. Bolinas marshes contain *populations* of rare *annual* plants, and formerly supported California clapper rails. Bolinas was the *type locality* for the rare *Astragalus* *pycnostachyus* var. *pycnostachyus* (coastal marsh milkvetch), a species now thought to be *extirpated* there.

Drake's and Limantour esteros, located along Drake's Bay at Point Reyes, consist of extensive sandy shoals, flats, *Zostera marina* (eelgrass) beds, and a few major *tidal* channels with salt *marsh* along the margins. Their waters are primarily marine, but numerous small streams, mostly seasonal, empty into them. *Zostera marina* beds thrive in the clear estero waters, which have low discharge of fine *sediments* from upland drainages and little resuspension of fine *sediment* from tideflats. Salt *marsh* is confined primarily to the heads and fringes of the smaller bays, alluvial areas of local streams, and shoal areas fringing Limantour spit. Most salt marshes here appear to be young, based on historical maps. Most smaller salt marshes have relatively small and simple *tidal* creeks, and bayward edges that show evidence of growing shoals and bars stabilized by vegetation. Some tidelands were *diked* in the 19th century for *impoundments*, but some of these barriers have been breached and culverted (*tidal* flows partially restored by large pipes under roads) to restore *tidal* action.

Drake's and Limantour Estero marshes have relatively infrequent, but abundant, stands of *Spartina foliosa*, which have expanded significantly in the 1990s (Baye pers. comm. 2004). *Spartina foliosa* was present in Drake's Estero prior to 1950 (Howell 1949), but was reported to be absent in Tomales Bay as recently as the 1970s (MacDonald and Barbour 1974). *Scirpus pungens* (common threesquare bulrush) occurs along sandy *marsh* shorelines of Drake's Estero where fresh groundwater influence is significant. *Marsh* plains in the esteros are similar to those of Bolinas Lagoon, with turfy low vegetation that supports significant *populations* of *halophytes*, some of which are regionally uncommon or globally rare. Important *populations* of *Astragalus pycnostachyus* occur in Drake's and Limantour Esteros, as does most of the total *population* of *Polygonum marinense* (Marin knotweed). The esteros support large *populations* of *Cordylanthus maritimus* ssp. *palustris* (Point Reyes bird's-beak), regionally rare salt *marsh ecotypes* of *Castilleja ambigua* ssp. *ambigua* (johnny-nip, salt marsh owl's-clover), and the rare *Castilleja ambigua* ssp. *humboldtiensis* (Humboldt Bay owl's-clover).

Tomales Bay is a feature of the San Andreas fault, like Bolinas Lagoon and Bodega Harbor, with a wide mouth and an incomplete sand barrier (Dillon Beach). Two relatively large streams, Walker Creek and Lagunitas Creek, establish local estuarine gradients within Tomales Bay. The largest salt marshes are associated with the alluvial deltas of these creeks. The Lagunitas Creek delta expanded in the 19th century due to *sediment* deposition from watershed erosion, and most of it was *diked* for agriculture and railroad alignments. Similarly, the Walker Creek delta has expanded rapidly in recent decades (U.S. Geological Survey, Tomales quadrangle) due to watershed erosion. Pastures in *diked* baylands at the south end of Tomales Bay are still maintained today, but railroad *berms* have been breached and habitat restored to *tidal* flats and salt *marsh*. Tomales Bay also supports extensive *tidal* flats and sub*tidal Zostera marina* beds, with strong influence of marine sands and seawater near the mouth. Silts dominate near-surface *sediments* at the head of the bay, although local headland sources of coarse *sediments* are common. These are eroded and re-deposited in high *marsh* zones. The bay margins are indented with coves and numerous gulches (intermittent and *perennial* stream valleys) associated with small deltas, beaches, and discrete pocket salt marshes, *riparian* vegetation, or *lagoons*.

The importance to the health of Tomales Bay and the outer Marin coastline of restoring hydrological connectivity between Giacomini Ranch, Olema Marsh, and Tomales Bay is underscored by the relative scarcity of coastal wetlands present along the central California coastline (State Coastal Conservancy *in litt.* 2007). The State Coastal Conservancy, in September 2007, recommended funds be spent to implement the Giacomini Wetland Restoration Project on a 225-hectare (550-acre) site at the southern end of Tomales Bay, purchased in 2000 by the National Park Service (NPS) and managed by Point Reyes National Seashore. Construction efforts aimed at restoring Giacomini Ranch to wetland were largely complete as of December 2008; however, additional construction may occur in future years in the Giacomini Ranch and Olema Marsh, should the NPS and Point Reyes National Seashore Association be able to secure additional funding. These restoration activities include continued restoration of hydraulic connectivity in Olema Marsh and further lowering of high elevation areas in Giacomini Ranch, as well as continued treatment and retreatment of *non-native invasive* plant species. In addition, the Park Service continues to seek funding to implement the public access portion of the project.

The vegetation of the Tomales *marsh* plains is similar to that of Bolinas Lagoon and Drake's/Limantour Estero. *Spartina foliosa* occurs primarily at the head of the *estuary* in the Lagunitas Creek delta marshes, but also occurs at some smaller deltas. The salt *marsh*es of Tomales Bay also support some of the largest *populations* (collectively and individually) of rare salt *marsh* plants, such as *Cordylanthus maritimus* ssp. *palustris* and *Castilleja ambigua* ssp. *humboldtiensis*. The *tidal* flats are important economically for oyster culture, and the extensive *tidal* flats are critically important for migratory shorebirds and waterfowl.

Bodega Harbor is an *embayment* sheltered by Doran Beach, a low sand spit. It is structurally similar to Bolinas Lagoon, and shares a geologic association with the San Andreas fault. The harbor inlet is maintained in an open state. The *lagoon* supports extensive sand and mud inter*tidal* flats, abundant sub*tidal Zostera* beds, dredged sub*tidal* areas (channel, turning basin, marinas), and local salt marshes. Salt marshes are associated with deltas of small seasonal streams, dredge spoil fans, and wave-built shoals and bars. Inter*tidal* and sub*tidal* habitats total approximately 356 hectares (880 acres; Standing *et al.* 1975). Salt *marsh* area is less than 40 hectares (100 acres), most of which is recent in origin. Salt *marsh* probably expanded on the Cheney Gulch delta after increased erosion due to grazing and cropping within the watershed in the 19th century. *Tidal* drainage systems are feebly developed, but some well-developed *tidal marsh pans* occur within the *marsh* plain of Cheney Gulch delta. Much of this *marsh* was destroyed by filling, the filled area is now a dredge disposal site and sewage treatment plant. In the mid-1980s, a large spill of dredge spoil was deposited over *marsh* and *mudflats*. It has since re-vegetated. Wildlife enhancement ponds with damped *tidal* circulation for waterbirds were excavated at this *marsh* in the 1990s.

The vegetation of the salt marshes at Bodega Harbor is similar to that of Tomales Bay, but has very little *Spartina foliosa*. Local *freshwater* and *brackish* non-*tidal marsh* areas are adjacent to salt *marsh* at the east end of Doran Beach spit, and seasonal *freshwater* wetlands occur in *dune slacks* within the Salmon Creek Beach dunes.

d. San Mateo coast

In San Mateo County and northern Santa Cruz County, small *tidal* marshes, often *brackish* in character, occur at coastal stream mouths that are open to *tidal* flows for much of the year. These compressed estuaries often develop small *tidal* marshes on alluvial flood deposits (point or channel bars, flood *tidal* deltas) or along gently sloping creek shorelines. The largest of these is the Pescadero Creek Estuary. Despite their relatively small size, these *tidal* marshes are often as rich in species as larger marshes in San Francisco Bay. They probably provide stepping stone connections for long-term dispersal and *gene* flow among *tidal marsh populations* along the coast. They also provide important habitat for some rare species, such as *Astragalus pycnostachyus* var. *pycnostachyus*, which has over half its current range supported by these small marshes. The federally endangered tidewater goby intermittently inhabits these stream mouth *lagoons* and estuaries. Examples occur at San Gregorio Creek, Pomponio Creek, Pescadero Creek, and Gazos Creek. Smaller stream mouths with similar habitat occur at Scott Creek and Waddell Creek.

e. Monterey Bay (Elkhorn Slough, Salinas River mouth)

Elkhorn Slough is the largest *tidal* salt *marsh* system between San Francisco and Morro Bay, and was the first estuarine sanctuary in the nation. It is similar in size to Morro Bay, including approximately 600 hectares (1,440 acres) of *tidal marsh* within an *estuary* of nearly 1000 hectares (2,400 acres; Browning 1972). Elkhorn Slough became a sheltered *tidal estuary* with salt marshes approximately 3,000 years ago. By historical times, it was associated with the mouth of the Salinas River, with a *tidal* inlet that constricted *tidal* flows and formed an intermittent beach-dammed *lagoon*/*brackish tidal marsh* (Browning 1972). *Freshwater* discharges from *fluvial* and spring sources, in conjunction with restricted *tidal*flows caused by the *barrier beach* and inlet, probably maintained a dynamic *brackish*-salt *marsh ecotone* over much of the *estuary*. Thick *freshwater* peat deposits occur at the head of the *slough*, particularly McClosky Slough, now a non-*tidal freshwater* pond and *marsh* (Schwartz *et al.* 1986).

Large areas of the Elkhorn Slough *tidal* marshes were *diked* and drained for agricultural use in the 19th century. Approximately 50 percent or 405 hectares (1,000 acres) of salt *marsh* habitat was lost between 1870-2003 due to human impacts (Van Dyke and Wasson 2005). Approximately 325 hectares (800 acres) were converted to solar salt ponds in the 20th century, about 62 hectares (153 acres) of which remain today as salt *pan* habitat managed for shorebirds and western snowy plovers (*Charadrius alexandrinus nivosus*) by California Department of Fish and Game (Elkhorn Slough Tidal Wetland Project Team 2007). The Salinas River mouth was diverted to the location of a flood breach, and the former channel managed as a low flow channel bypass. In the 1940s, the system was altered by the construction of a marina and a permanent large *tidal* inlet stabilized by jetties. The inlet increased the *tidal prism* of the *slough*, causing chronic erosion of *tidal* channel banks and salt marshes, and greatly diminishing *brackish* to *freshwater* influences on the *tidal marsh*. *Salinity* in the western part of the *estuary* is now very close to marine *salinity* (Broenkow 1977). A railroad *dike* and tidegate at the southeastern corner of the *estuary* have established a local *brackish microtidal marsh* and shallow *lagoon* habitat.

Tidal salt *marsh* vegetation of Elkhorn Slough is similar to that of Morro Bay. *Tidal* channels lack *Spartina foliosa*, and *marsh* plains consist primarily of relatively prostrate *Sarcocornia pacifica* (pickleweed)-dominated vegetation (Macdonald and Barbour 1974, Baye pers. comm. 2004). Despite the lack of *Spartina*, Elkhorn Slough supported California clapper rails from before the diversion of the Salinas River and permanent stabilization of the *tidal* inlet (Silliman 1915) through at least the 1960s (Browning 1972). No records of clapper rails have been confirmed there since the 1980s, and rails are presumed to have only vagrant status today (C. Wilcox pers. comm. 2005). Terrestrial habitats adjacent to Elkhorn Slough *tidal* marshes are dominated by heavily grazed dairy pasture. Transitional *ecotones* and high salt *marsh* are poorly developed, disturbed, or lacking along most of the *estuary* margin. No rare estuarine plant *populations* are reported from Elkhorn Slough.

f. Morro Bay

Morro Bay is relatively small, but its *estuary* supports the only sizeable maritime *tidal* marshes (*brackish* and salt *marsh*) on the southern central coast of California. It consists primarily of extensive *tidal mudflats* and sandflats with significant areas of *Zostera marina* (eelgrass) and large *tidal*channels. Extensive salt *marsh* plains occur primarily along the eastern shore, patterned over the convergent deltas and distributary channels of Chorro Creek and Los Osos Creek drainages. Much of the *tidal marsh* area developed on these deltas in historical times. Smaller fringing salt marshes occur along the bay margin of the large barrier spit and dune system. *Brackish tidal marsh ecotones* occur near the deltaic mouths of Chorro and Los Osos creeks. The salt *marsh* acreage of Morro Bay increased from approximately 113 hectares (280 acres) in 1895 to approximately 170 hectares (420 acres) in 1951. Sedimentation and *marsh* growth declined by the 1960s, and there is an ongoing local effort to reduce sedimentation of the bay. Morro Bay has an inlet stabilized by a jetty for navigation. Historically, it naturally supported a permanently open *tidal*inlet that permitted strong *tidal* flushing (Gerdes *et al.* 1974). Periodic dredging of the navigation channel at the *tidal* inlet is located away from *tidal marsh* areas (Gerdes *et al*. 1974).

Morro Bay *tidal* wetlands have experienced relatively minor alteration by historical diking and filling compared with other estuaries in central and northern California. They retain excellent examples of *brackish riparian ecotones*, high *marsh*/upland *ecotones* (especially diverse *marsh*-dune *ecotones*), and many types of *salt pans*. Relatively large *salt pans*, composed of sandy/silty flood deposits and *hypersaline* depressions, occur near the banks of Los Osos Creek. Many smaller ponded depressional *pans*, ranging from *brackish* to slightly *hypersaline* conditions, are widely distributed within and along the edges of the marshes of the Chorro Creek and Los Osos Creek deltas. These smaller *pans* provide high *tide* foraging roost habitat for waterfowl and shorebirds, and flats of the larger *pans* provide nesting habitat for killdeer (*Charadrius vociferus*; Baye pers. comm. 2004). Unique features occur at the south end of Morro Bay where the large, steep mobile dunes cause marginal bulge and rapid uplift of extensive fractured *marsh* peat blocks as the dunes advance (Baye pers. comm. 2004). These peat blocks become colonized by high *marsh* and upland (dune *ecotone*) vegetation. Numerous *freshwater* seeps from the dunes also establish steep *brackish marsh ecotones* in the coves between dunes.

The community of Los Osos gets its water entirely from the underlying groundwater, predominately the lower aquifer. The lower aquifer is presently experiencing seawater intrusion at approximately 460 acre-feet per year. The portions of the aquifer that have already been intruded are likely permanently lost from the *freshwater* supply (San Luis Obispo County 2008*a*).

Like other central and northern California salt marshes with sandy substrates and influenced by marine *tidal* waters, most of the salt *marsh* vegetation at Morro Bay is low and turf-like, dominated by short *Sarcocornia pacifica* (pickleweed) and *Triglochin concinna* (creeping arrow-grass) in the middle *marsh* plain; and *Distichlis spicata* (saltgrass), *Frankenia salina* (alkali-heath), and other species near creek *levees*. *Spartina foliosa* is notably absent (MacDonald and Barbour 1974); pioneer salt *marsh* vegetation is often *Sarcocornia pacifica*. Morro Bay supports the only remaining natural *population* of *Suaeda californica* (California sea-blite), and a *disjunct population* of *Cordylanthus maritimus* ssp. *maritimus* (salt *marsh* bird's beak) that exhibits some intermediate traits of the northern subspecies *palustris* (Chuang and Heckard 1986). Morro Bay *tidal*marshes support other rare or unique botanical features. The northernmost salt *marsh population* of *Lasthenia glabrata* ssp. *coulteri* (Coulter's goldfields), a subspecies of smooth goldfields, occurs near Sweet Springs Marsh. The northernmost *population* of *Atriplex watsonii* (Watson's saltbush) and the only *tidal marsh populations* of *Solidago confinis* (southern goldenrod) extant in California occur there.

Morro Bay *tidal* marshes have no major inter*tidal non-native* plant invasions. *Cardaria pubescens* (white-top), a European weed similar to *Lepidium latifolium* (perennial pepperweed), is a problem in *brackish* upper reaches of the *tidal marsh* where seed washes down from higher in the watershed (M. Walgren pers. comm. 2005). *Carpobrotus edulis* (iceplant), *Eucalyptus* trees, and various other *non-native* trees and shrubs (*Myoporum* spp. and *Cupressus macrocarpa*) cause locally intensive invasions near the *marsh* edge.

The extensive tideflats and *salt pans* of the Morro Bay wetlands support abundant waterfowl and shorebirds of the Pacific flyway, including the largest *tidal* flat and shallow *lagoon* areas between Elkhorn Slough (Monterey County) and Mugu Lagoon in southern California. Morro Bay has been designated an Important Bird Area (IBA; National Audubon Society 2009), with concentrations up to 20,000 shorebirds estimated to use the *tidal* habitat there (Page and Shuford 2000). From 59 to 89 bird species have been observed. Shorebirds (particularly willets [*Catoptrophorus semipalmatus*], marbled godwits [*Limosa fedoa*], western sandpipers [*Tringa solitaria*], curlews [*Numenius* ssp.], dunlins [*Caladris alpina*], dowitchers [*Limnodromus* ssp.], and sanderlings [*Caladris alba]*) are the most abundant, followed by waterfowl (dominated by black brant (*Branta bernicla*), but commonly including pintails (*Anas acuta*), green-wing teal (*Anas crecca*), lesser scaups (*Aythya affinis*), widgeons (*Anas americana*), ruddy ducks (*Oxyura jamaicensis*), and buffleheads (*Bucephala albeola*). An important heron rookery occurs at Fairbank Point toward the north end of the bay, supporting up to 74 great blue heron nests and 100 black-crowned night heron nests (Gerdes *et al*. 1974). Morro Bay also supported a small historical *population* of clapper rails, which has been interpreted as either California clapper rails or light-footed clapper rails (Brooks 1940), but is now *extirpated*. California black rails occur in Morro Bay *tidal* and *brackish* marshes (Gerdes *et al*. 1974).

Tidewater goby have not recently been found in Morro Bay itself, but occur regionally in nearby creek mouths (U.S. Fish and Wildlife Service 2005), and have the potential to colonize in Morro Bay. The waters and eelgrass beds of Morro Bay are important habitat for a variety of fish species, including Pacific herring (*Clupea harengus*), pipefish (*Syngnathus* sp.), and rays.

Terrestrial habitats that support endangered species occur adjacent to, and contiguous with, Morro Bay *tidal* marshes. These include *Holocene* dunes (sand deposits of the barrier spit), important habitat for the threatened western snowy plover, and ancient *Pleistocene* dunes of the eastern bay (sandy brownish soils with coastal chapparal and scrub). The *Pleistocene* dunes provide habitat for the endangered Morro Bay kangaroo rat (*Dipodomys heermanii morroensis*; U.S. Fish and Wildlife Service 1999) and the endangered Morro shoulderband snail (*Helminthoglypta walkeriana*; U.S. Fish and Wildlife Service 1998), which can occur in *non-native Carpobrotus edulis* (iceplant) vegetation of dunes adjacent to *tidal marsh*.

D. Threats to California tidal marsh ecosystems

Conditions and factors that threaten most or all of the species covered in this draft recovery plan are described below. These are often threats to the *tidal marsh* ecosystem that supports *tidal marsh* species. Other threats to individual *tidal marsh* species may exist and are described under Reasons for Decline and Threats to Survival in the respective species account in Chapter II.

Section 4(a)(1) of the Endangered Species Act identifies five major categories of threats, which are considered when a species is listed. These are (a) the present destruction, modification, or curtailment of its range, (b) overutilization for commercial, recreational, scientific, or educational purposes, (c) disease or predation, (d) the inadequacy of existing regulatory mechanisms, and (e) other natural or manmade factors affecting its continued existence. Threats currently facing the ecosystem in general are categorized below according to these five factors. Major categories of these general threats include: habitat loss and fragmentation, habitat degradation and disturbance, *invasive non-native* species, risks of small *populations*, and climate change.

Factor A: The present destruction, modification, or curtailment of its habitat or range.

Habitat loss and fragmentation

Habitat loss. The greatest historical and present threat to *tidal marsh* ecosystems and the species they support is the destruction and alteration of habitat. Loss of coastal wetland habitat to urban and industrial development has been extensive in California, with 90 percent of these wetlands being lost since settlement of the region (Goals Project 1999). Roughly 90 percent of original *tidal marsh* habitat has been altered or destroyed in Humboldt Bay (A. Pickart, S. Harris pers. comm.). Only eight percent of the original pre-historical *tidal* marshes remain in the San Francisco Estuary (Goals Project 1999). By 1930, one-half of the historical *tidal marsh* in the South Bay had been converted to salt ponds by Leslie Salt Company (later purchased by Cargill Salt Division). Leslie Salt expanded its operations to the North Bay in 1952, where it ultimately converted 14,500 hectares (36,000 acres) of *diked* agricultural baylands into salt ponds (Goals Project 1999). Many of the last remaining large tracts (hundreds of contiguous acres) of *undiked* *tidal* salt *marsh* in the South Bay were converted to salt ponds in the early to mid-1950s (U.S. Army Corps of Engineers, San Francisco District, aerial photograph and map archives). Effectively irreversible conversion of former *tidal marsh* to residential and industrial areas around Oakland, Alameda, Foster City, and Redwood City was complete by the 1960s, although some residential extension within *diked* baylands of Redwood City continued through the 1990s.

Habitat fragmentation and edge effects. Habitat fragmentation occurs when *tidal marsh* habitat, once extensive and contiguous, is divided into relatively small discontiguous fragments. Fragmentation complicates the impact of habitat loss by reducing *tidal marsh populations*, not to one contiguous *population* a tenth of its former size, for example, but to many isolated tiny *populations* on habitat fragments of varying size, shape, and condition. In addition to the difficulty of supporting a *viable population* on a habitat fragment of limited area, *marsh* fragments may lack the full range of habitat features needed by a species throughout its life cycle. For example, a fragment might contain feeding and nesting habitat for the salt *marsh* harvest mouse, but completely lack refuge from high *tides* or *storm surges*.

As remaining *marsh* areas are reduced in size, *edge effects* become increasingly severe. Smaller *populations* and smaller (or narrower) habitats have less ability to absorb or buffer adverse impacts from outside influences, such as predation, human disturbance, or pollution.

Local extinction rates in habitat fragments generally increase as habitat area decreases and distance from neighboring *populations* increases (Hansk 1999). Correspondingly, breeding *populations* of species with limited *population* densities and dispersal, such as the California clapper rail, have generally been lost from smaller and more isolated *tidal marsh* fragments, and are at risk in many fragments where they still persist.

Habitat degradation and disturbance

The quality of remaining *tidal marsh* habitat for *tidal marsh* species in central and northern California has been altered and degraded by human actions, including diking, habitat conversion in buffering lands, flow and *salinity* alteration, contamination by pollutants, and actions causing disturbance. Habitat fragmentation may be considered a form of habitat degradation. Also, invasion by *non-native* species often results in habitat degradation or disturbance. Many factors cause habitat degradation or disturbance in California *tidal* marshes; some of the most common are summarized below.

Diking. Many hundreds of miles of *dikes* or *levees* dissect former *tidal* areas of the San Francisco Bay Estuary and Humboldt Bay. Most were first constructed years ago to create salt ponds, allow agriculture, or for purposes related to flood control. *Dikes* require periodic maintenance, typically by clamshell dredges that deposit bay spoil material on the tops and sides of the *dikes*.

Maintenance of *dike* systems continues to isolate *tidal* marshes into areas too small to develop complex *tidal*drainage networks. *Dikes* ordinarily hinder normal circulation of *tidal* flows and drainage, with the result that *diked* areas have less *tidal* amplitude and flushing, and are either drier or wetter (or both, seasonally) than undisturbed *marsh*. Vegetation and soils are altered, for example, by persistent inundation or evaporative concentration of salts. Drying of *marsh* *sediments* has resulted in increased decomposition of organic matter in the soil or peat, causing *subsidence* of the ground surface. Groundwater pumping may also contribute to *subsidence*. Many *diked* areas are today substantially below sea level as a result, in some areas by more than 6 meters (20 feet).

Diking is often associated with artificial channelization, where drainage or flood flows constricted by *dikes* are directed in straightened, shortened, deepened, and otherwise altered channels to the bay. Channelization, along with diking and fragmentation of *marsh* into small areas, has led to a reduction in the amount and complexity of natural creek channels in remaining *tidal marsh*, which normally provides important habitat for many *tidal marsh* species. Natural *tidal* channels require normal *tidal* flows and adequate space and drainage to develop.

Dikes are now the only upland edges of many *tidal marsh* remnants. *Dikes* generally are too steep, narrow, and weedy to be high quality high-*tidal refugia* for *tidal marsh* animals. *Dikes* also greatly facilitate site access for both people and predators. Mammalian predators, especially *non-native* red foxes (*Vulpes vulpes*) and Norway rats (*Rattus norvegicus*), use *levees* as movement *corridors* and denning/nesting sites. In many small remnants of *tidal marsh* in the San Francisco Estuary, *dikes* allow predator access across the entire remaining habitat. *Dikes* allow predators to travel distances out into baylands that would otherwise be naturally isolated from frequent contact with terrestrial predators. Access by people and pets also creates disturbance that may affect sensitive species.

Loss of ecotones. Prior to settlement of the bay area by Europeans, *tidal* baylands graded landward into transitional zones (or *ecotones*) of low-lying moist grassland or willow thickets, including some *vernal pool* grasslands, and then into upland areas (Goals Project 1999). Appropriately sized and structured *ecotones* are a critical component of California clapper rail and salt marsh harvest mouse habitats, especially in urbanized settings. These areas provide two primary benefits to adjoining wetlands by (1) absorbing and deflecting disturbances originating in upland areas, and (2) providing upland *refugia* during high *tide* and flood events, both of which ultimately influence habitat quality and carrying capacity of *tidal* marshes for clapper rails.

In particular, the presence of a broad *marsh*/upland *ecotone*, which may be the only escape *refugia* during high *tide* situations, is crucial to the viability of small mammals, such as salt *marsh* harvest mice. In flood years, these areas may be responsible for harboring most of the surviving mice, which then repopulation the adjacent *marsh* in future years. Without adequate *ecotone*, viability of salt marsh harvest mouse *populations* will likely be low in *tidal* marshes, particularly in light of projected climate change (Albertson *in litt.* 2009*a*).

Much of the historical development around the bay has not allowed for these buffering transitional zones between urban or industrial areas and *tidal* marshes. Refuse dumped or blown in from adjacent urban areas also affects habitat quality by attracting predators or damaging habitat. Even in rural areas, transitional and upland vegetation has been replaced with *non-native annual* grasses, and livestock graze up to and sometimes into the *marsh*. Consequently, there has been extensive loss of high *marsh*-to-upland transition area and *ecotones*, and urban influences and disturbances frequently border directly on remaining *tidal marsh*. Shellhammer (unpubl.

research) found that the adjacent upland edge (*i.e.,* the *ecotone* between *marsh* and upland) exists today in only 2.5 percent of the South Bay's edge.

Disturbance. Numerous routine human activities can cause disturbance to sensitive species, including, for example, maintenance activities for *dikes*, *levees*, flood control, dredge locks, pipelines, and utility rights-of-way; vegetation control activities; recreational uses including boating, hiking, biking, dog-walking, bird watching, and horseback riding; human and domestic and feral animal incursion from adjoining developments; ditching or spraying for mosquito control; and use of all-terrain/off-road vehicles in baylands (Goals Project 1999). Trampling by livestock and other animal *populations* sometimes causes physical disturbance to *tidal marsh* and ecotonal habitats.

Salinity changes. Both fresher and more saline conditions alter *tidal marsh* habitats, often with adverse consequences to the species that live there. Diking can alter *salinity* conditions, both in water and soils. In fact, concentrating salt was a primary reason for some *dike* construction. Diking reduces *salinity* when it blocks entry of the *tides* and impounds rainfall or *freshwater* drainage. *Salinity* can be controlled in some *diked* habitats with flow control structures (tide gates).

Wastewater discharges, which are usually lower in *salinity* due to pollutant discharge requirements pursuant to Federal and State water quality laws, can alter natural *salinity* levels in *tidal* waters. For example, *freshwater* discharges on the order of 120 million gallons per day from the San Jose Water Pollution Treatment Plant have led to the conversion of approximately 120 hectares (300 acres) of salt *marsh* to fresh and *brackish marsh* near the southern end of San Francisco Bay since about 1970 (H.T. Harvey and Associates 1997), which has been detrimental to the clapper rail and other species. Additional acreage where the *marsh* vegetation has not been fully converted may also have been degraded by these discharges. Wastewater discharges and other urban runoff alter *freshwater* input to varying degrees around the San Francisco Bay and other estuaries.

Another form of *salinity* alteration is occurring in Suisun Marsh. Under natural conditions, Suisun Marsh *salinity* would be closely linked with Delta outflows and *freshwater* inflows from other creeks in the Suisun Marsh watershed, with considerable seasonal variation, from nearly fresh in the spring, to *brackish* in the fall. During high rainfall years, lowered summer soil *salinity* would favor conversion of middle *tidal marsh* zones to *Scirpus*-dominated vegetation, causing decline of *Sarcocornia-Distichlis* (pickleweed-saltgrass) vegetation. During dry years, *Sarcocornia-Distichlis* vegetation would re-establish dominance and *Scirpus* vegetation would retreat (Suisun Ecological Workgroup 2001). In 1998, the California Department of Water Resources constructed and began operating the Suisun Marsh *salinity* control gates (SMSCG) in Montezuma Slough to maintain low summer and fall salinities in portions of the *marsh*. Operation of the *salinity* control gates has widespread effects on water and soil *salinity*, raises water levels in the *marsh*, and reduces *tidal*range and circulation. Artificially stabilizing salinities at low levels during the summer and fall subdues the climate-driven pattern of vegetation fluctuations. These low *salinity* levels are harmful to species that favor plant communities of higher or more variable *salinity*, especially plants that require bare areas in salty soils for colonization. Water quality standards that relate to the operation of the Suisun Marsh *salinity* control gates were modified by the State Water Resources Control Board in light of broader estuarine ecological considerations (State Water Resources Control Board 1999). Water quality standards for *salinity* were modified in western Suisun Marsh to allow greater climate-driven fluctuation. However, the artificially narrow low *salinity* range is still enforced in eastern Suisun Marsh.

Gradual changes in *salinity* in California estuaries are projected to result from sea level rise pushing saline ocean water further inland (Knowles 2002, Knowles and Cayan 2002, Wilkinson 2002). Sea level rise is an ongoing process accelerated by climate change. See the paragraph below on climate change and sea level rise.

Invasive species

One of the most pressing threats to the *tidal* marshes of California is invasion and modification of the ecosystem by *non-native* species—in the San Francisco Bay Estuary in particular, by the eastern cordgrass *Spartina alterniflora*. *Non-native* plant species capable of living in *tidal* marshes have invaded and profoundly altered vegetation, or threaten to do so, over extensive areas. *Non-native* plant species of greatest concern are those that (1) become so abundant that native plant species are diminished significantly in *population* size or displaced altogether, (2) become extensively dominant or develop nearly monotypic (single-species) stands, (3) colonize habitats naturally lacking in vascular plants, such as *tidal* flats, or (4) are *annuals* that thereby provide no escape cover during winter high *tides* because they are simply a plant skeleton that predators can see through. *Invasive* species cause major impacts to the structure of vegetation, species competition, and composition within communities, and even to the soil-building properties of the *tidal marsh* ecosystem. Plant invasions harm *tidal marsh* animal *populations* by altering food availability or habitat structure. Invasions by *non-native* animals also affect *tidal marsh* species. To date, most animal impacts of concern have been those of *non-native* predators, such as red fox and Norway rats, on native prey species.

Invasive Spartina. Of several *invasive non-native Spartina* species (**Figure I-4**) found in San Francisco Bay, the most abundant is *Spartina alterniflora* (smooth cordgrass) and its hybrids. This plant, native to *tidal* marshes of the Atlantic coast and Gulf of Mexico, is arguably the greatest present threat to the maintenance and restoration of native salt marshes in the San Francisco Bay Estuary. Outlying infestations in Bolinas Lagoon and Tomales Bay have been found. A separate and earlier invasion at Willapa Bay, Washington State, resulted in extensive conversion of *tidal mudflats* to dense, continuous, monotypic *S. alterniflora marsh* (Mumford *et al*. 1990). Unless controlled, *invasive non-native Spartina* has the potential to continue to spread extremely rapidly throughout the San Francisco Estuary, and to dominate and transform its *tidal* ecosystems within a human generation (Ayres *et al.* 2003, 2004*a*, 2004*b*; Zaremba 2004). It also has the potential to spread and extensively invade Pacific *tidal* marshes and *mudflats* south and north of the Golden Gate. However, with control efforts recently begun, there is optimism that the invasion will be controlled (see Conservation Efforts section).

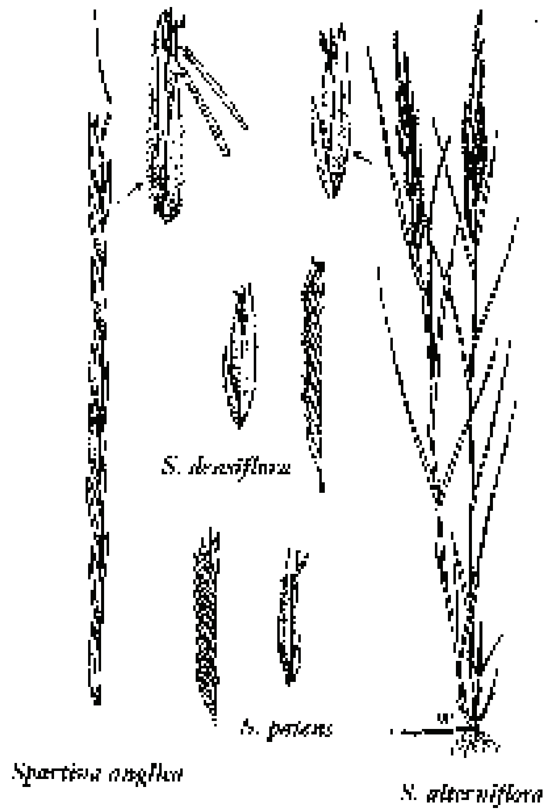


FIGURE I-4. **Invasive *Spartina*** (from Invasive Plants of California's Wildlands, edited by C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, with permission from University of California Press © 2000

Spartina alterniflora is a coarse *perennial* grass that re-sprouts annually from thick *rhizomes* (underground stems), and spreads rapidly to form extensive colonies on *mudflats*, marshes, *tidal* creeks, and even rip-rap. It reproduces from seed and also by re-growth from rhizome fragments. In the bay region, it is much taller and faster-growing, grows more densely, and occupies a wider *tidal* range than the native *Spartina foliosa* (California or Pacific cordgrass) (Callaway 1990, Daehler and Strong 1996). More information on native *Spartina* is found in the *Spartina foliosa* species account in this draft recovery plan.

Spartina alterniflora was reportedly introduced to San Francisco Bay around 1976 from seed collected in Quinby, Virginia, and cultivated at Lafayette, California, for bank stabilization. The *non-native Spartina* hybridized with native *Spartina foliosa*, forming proliferations of hybrid plants (*hybrid swarm*s) that spread extensively and rapidly during the 1990s (Grossinger *et al*. 1998). Hybrid plants usually exhibit the large size and high growth rate more typical of *Spartina alterniflora*. These *hybrid swarms* swamp native *Spartina foliosa stigmas* with hybrid pollen and crowd out *Spartina foliosa* plants, with the potential to threaten this recently common species with extinction by *genetic* assimilation (Daehler and Strong 1997, Ayres *et al.* 1999). Sloop *et al.* (2008) found that *populations* of later generation hybrids and their seedling progeny were almost two-fold more homozygous than early generation hybrids. They posit that evolved self-fertility has contributed substantially to the rapid spread of hybrid *Spartina* in San Francisco

Bay. Change in the distribution of the infestation is now so rapid that it is not useful to detail it here; moreover, control efforts have begun. Instead, interested parties should consult recent monitoring reports (*e.g.,* reports of the *Invasive* Spartina Project http://www.spartina.org/).

Spartina alterniflora markedly alters *tidal marsh* habitat. With high biomass production and *sediment* trapping, *Spartina alterniflora* and hybrids are capable of *accretion* at unusual rates. The sediment-trapping efficiency of *Spartina* stands is proportional to density and height (Gleason *et al.* 1979, Knutson *et al*. 1982); and the density and biomass of *invasive Spartina* stands in San Francisco Bay exceeds that of the native *Spartina foliosa* by six to seven times (Callaway 1990). *Invasive Spartina* resists erosion and promotes sediment-trapping and *marsh* spread much more effectively than native *Spartina* in the South Bay (Josselyn *et al.* 1993, Newcombe *et al*. 1979). The explosive invasion has resulted in the evolution of novel hybrid forms that invade *tidal mudflats* and *tidal* creeks well below the ordinary *tidal* elevation limits of native *Spartina* (as low as 0.3 meter [1 foot] above mean low water) and higher elevation *marsh* plain habitats above the elevation range of native *Spartina* (Daehler *et al*. 1999, Baye 2004*a*). *Invasive Spartina* is capable of producing much more biomass than native salt *marsh* vegetation, and can form extensive, thick wrack*s* of *tidal* litter that can smother vegetation on *marsh* plains and the high *tide* line, as well as trapping *sediment*. The density, height, productivity, and inter*tidal* elevational range of *invasive Spartina* enable it to convert *mudflat* and small creeks to *marsh* with relatively few small *tidal* creeks. In fact, since the early 1990s, ditches, shallow *salt pans*, and small *tidal* creeks of long-established salt *marsh* at Ideal Marsh (near Alameda Creek) have filled in with *invasive Spartina* and *sediment* (Baye pers. comm. 2004). *Invasive Spartina* is filling in both higher and lower elevations once free of *Spartina* at Elsie Roemer Marsh (Alameda Island; Nordby *et al.* 2004). The likely long-term result of *invasive Spartina* habitat alteration is scarce *mudflats* and extensive monotypic *invasive Spartina marsh*, including extensive mid-to-upper elevation *marsh* plains invaded by hybrid *Spartina*.

Expansion of *invasive Spartina* over *mudflats* and *marsh* plains would be likely to destroy or degrade habitat for numerous *tidal marsh* plants and animals, including estuarine fish, migratory shorebirds, waterfowl, and most of the species in San Francisco Bay Estuary covered by this draft recovery plan. California clapper rail do make use of *invasive Spartina* stands, and it has been suggested that *invasive Spartina* expansion might even benefit the rail in the short-term. However, these statements extrapolate from observations of the invasion in its early stages, and neglect the long-term *marsh*-building, ecosystem-altering effects of *invasive Spartina*. Moreover, the likely strong negative effects of *invasive Spartina* on other species and the native ecosystem as a whole (Baye 2004*a*) cannot be ignored. For example, in a hypothetical uncontrolled invasion, the salt *marsh* harvest mouse would likely lose extensive habitat and food plant, *Sarcocornia*, to invasion by hybrid *Spartina* in the upper *marsh*. Plants that live near creek edges, such as *Grindelia stricta* var. *angustifolia*, are likely to be shaded or crowded out by *invasive Spartina*. For others that occur toward the upper edges of the *marsh*, or in more *brackish* areas, possibly outside the ecological range of *invasive Spartina* (though the full ecological range of *invasive Spartina* is not yet known), such as *Lathyrus jepsonii* var. *jepsonii* (Delta tule pea), effects are difficult to predict. Alameda song sparrows (*Melospiza melodia pusillula*) in invaded habitat suffer greater nest losses from building more nests at elevations subject to *tidal* flooding, mistaking *invasive Spartina* plants for safe nest sites. They also experience greater invasion by *marsh* wrens (*Cistothorus palustris*), possibly due to *invasive*

Spartina providing more attractive habitat for the aggressive wrens, which destroy some song sparrow eggs and hatchlings (Nordby *et al.* 2004). Similar impacts on Suisun and San Pablo song sparrows (*Melospiza melodia maxillaris* and *Melospiza melodia samuelis*) cannot be ruled out. Species that rely on open mud or salt *pan* areas likely to be invaded, such as the old man tiger beetle (*Cicindela senilis senilis*) and other tiger beetles, also could be adversely affected by *invasive Spartina*. Any species that relies, directly or indirectly, on *mudflats* or on one or several native *tidal marsh* plants for food would likely be reduced in numbers or distribution by development of extensive monotypic hybrid *Spartina* stands.

Invasive Spartina is likely to corrupt *tidal* restoration projects wherever abundant seed or pollen sources occur near receptive habitats, such as new tidally restored sheltered *mudflats* and young *marsh*. This has occurred at the Cogswell Marsh and the Oro Loma Marsh restoration areas near Hayward where hybrid *Spartina* is now the dominant plant. *Invasive Spartina* is extremely prolific. It explodes in distribution and, once established, is difficult, expensive, and damaging to remove. Therefore, it will be critical to control *invasive Spartina* prior to initiating nearby restoration projects. Otherwise, a "restoration" becomes an infestation, a control and rehabilitation problem, and a source of yet more *non-native* seed, *rhizomes*, and pollen.

Methods for controlling *invasive Spartina* exist, ranging from herbicides to flooding. Herbicides, such as imazapyr and glyphosate, have been used with reasonable, though varying, success. These chemicals have low vertebrate toxicity, and interfere with amino acid synthesis pathways in plants that are absent in humans (*i.e.*, humans do not synthesize the amino acids but obtain them from diet; Tu *et al.* 2001). Imazapyr requires less drying time after application, is less impaired by *sediment* on the leaves, appears to have lower vertebrate toxicity, and is cheaper to use effectively than glyphosate (Patten 2002). The surfactant used to carry and spread imazapyr may have a much greater effect on toxicity to fish than the active ingredient alone (King *et al.* 2004). A mixture of imazapyr and glyphosate also has been suggested (Crockett 2004).

Physical control methods, such as digging out *rhizomes*, are feasible with very small *Spartina* clones, but are very labor-intensive. Covering *invasive Spartina* with landscaping fabric has been used to kill small clones (Zaremba 2004). Disking and mechanical crushing were used extensively in Willapa Bay, Washington State, which resulted in temporary reduction in *Spartina* density in *mudflat* areas (Patten 2004), but were costly, equipment-intensive, and entailed ongoing effort and ongoing non-target impacts. *Diked* areas that can be opened and closed to *tidal* flow can be flooded for extended periods to kill *invasive Spartina*.

Biological control is being investigated in Washington, where there is no native *Spartina*. In California, however, because of the presence of native *Spartina foliosa*, which is very closely related to *Spartina alterniflora* (and even more closely to their hybrids), biological control of *invasive Spartina* may pose undue risk to the native ecosystem.

The Invasive Spartina Project, a major effort to eradicate *invasive Spartina* in the San Francisco Bay Estuary, is underway. See Tidal Marsh Conservation, Restoration, and Management (section I. E.), below, for more information. The Invasive Spartina Project's most recent surveys of *Spartina alterniflora* invasions (2006) indicate that control measures have resulted in a net reduction of area infested by *Spartina alterniflora* by 27 percent since 2001 (Invasive Spartina Project 2008). Of the total infested area, approximately 99 percent was found to be in the Central/Southern San Francisco Bay area and one percent in San Pablo Bay.

Other *non-native* species of *Spartina* have become established in California *tidal* marshes, although most are as yet at a lower level of invasion than *Spartina alterniflora*, and none seems likely to hybridize so readily with native *Spartina*. The Invasive Spartina Project has already targeted some of these other *non-native Spartina* infestations for control. Other *Spartina* species present are:

- *Spartina patens* is native to *tidal* marshes of the northern Gulf of Mexico and Atlantic coast. It is a fine-stemmed, creeping, matted grass, which forms dense turfs with tussocky (clumping) peaks in middle *marsh* plains and high *marsh* zones of salt or *brackish* marshes (Blum 1968). It spreads by creeping *rhizomes* and by seed (Mobberly 1956). *Spartina patens* increased exponentially after introduction to the Siuslaw Estuary in Oregon (Frenkel and Boss 1988). It has been present at Southhampton Bay (Carquinez Straits) since at least the 1960s (Munz 1968). There it occurs as an extensive, diffuse, and relatively continuous *colony* on the *marsh* plain adjacent to the south bank of a *tidal* creek, and as numerous, dense, discrete, essentially monotypic colonies on the *marsh* plain (P. Baye with D. Smith, S. Klohr pers. observ. 2000). The distribution and abundance of *Spartina patens* colonies at Southhampton Marsh suggests that it has been reproducing both by seed and clonal growth for many years, and is continuing to spread. Two other *populations* of *Spartina patens* have been reported in the *estuary*; one from San Bruno has not been confirmed (D. Smith pers. comm. 2000). The other is lower Tubbs Island and Tolay Creek in the San Pablo Bay National Wildlife Refuge (Baye pers. comm. 2004). The extent of the *population* at Lower Tubbs Island appears to be small compared with Southhampton Marsh, but further surveys are needed. If *Spartina patens* spreads in San Francisco Bay it has the potential to dominate middle and high *marsh* habitat, displacing *Sarcocornia pacifica,* and converting habitat used by all listed *tidal marsh* species in the region to unsuitable conditions.

- *Spartina densiflora* (dense-flowered cordgrass) is a tussock-forming grass of the middle and high *marsh* zones. The species is widespread and locally dominant in Humboldt Bay and portions of Richardson Bay and Corte Madera Creek (Marin County). It was probably introduced to Humboldt Bay before 1900 by ballast from lumber ships, and now covers 330 hectares (814 acres), or 94 percent of the salt *marsh* (Tatum *et al.* 2005). Whereas it had been thought to be restricted to mid-elevation salt *marsh* in Humboldt Bay, it has been found spreading into the high-elevation salt *marsh* (Pickart 2001). The species also was introduced by plantings in Creekside Park in Richardson Bay (San Francisco Bay) in 1977 (Spicher and Josselyn 1985, P. Faber pers. comm. 1998). It spread spontaneously around Richardson Bay and to a *disjunct population* at Point Pinole (San Pablo Bay) by the 1990s.

Because of its ecological and geographic distribution, *Spartina densiflora* may be a threat to habitat suitability of *tidal marsh* for salt *marsh* harvest mice, California clapper rails, and *Cordylanthus mollis* ssp. *mollis* (soft bird’s beak), as well as many species of concern, such as *Cordylanthus maritimus* ssp. *palustris* (northern salt marsh bird’s-beak) and *Castilleja ambigua* spp. *humboldtiensis* (Humbodlt Bay owl’s clover). Control of *Spartina densiflora* by herbicide application and manual removal at Point Pinole has initially been fairly successful (D. Smith pers. comm. 1998), although some re-emergence has occurred (P. Baye unpubl. data 1999). In Humboldt Bay, studies on removal of *Spartina densiflora* by mowing and digging are underway and show promise (Tatum *et al.* 2005). In fact, a recent study at the Lanphere Dunes Unit of Humboldt Bay National Wildlife Refuge found that *Castilleja ambigua* ssp. *humboldtiensis* responded in a dramatic and positive manner to *Spartina densiflora* removal conducted in 2006-2007 (U.S. Fish and Wildlife Service 2009*a*).

o *Spartina anglica* (English cordgrass) is a fertile polyploid hybrid that originated when *Spartina alterniflora* of North America and *Spartina maritima* (small cordgrass) of Europe came into contact in England (Raybould *et al*. 1991). It is ecologically similar to *Spartina alterniflora*. It has become a threat to *tidal mudflat* habitats and eelgrass beds in Britain, New Zealand, and Australia (Adam 1990). *Spartina anglica* was introduced to Creekside Park, Richardson Bay, in 1977 from Puget Sound where it is also exotic (Spicher and Josselyn 1985), and it persisted at this location through 1998 (Grossinger *et al*. 1998). It is not clear whether its very restricted invasion is due to inherent or circumstantial factors. A long latency phase of significant invasions elsewhere suggests that a history of slow spread is not an indicator of low risk of invasion (Gray *et al*. 1991). Because of its invasiveness in other places it has been introduced, *Spartina anglica* should be regarded as a threat.

Lepidium latifolium (broadleaf or perennial pepperweed, also known as peppergrass [although it is not a grass and does not resemble one], white-top, and slough mustard). *Lepidium latifolium* is native to salt marshes of the Mediterranean, where it is not reported as a dominant or aggressive species (Chapman 1964). This *perennial* herb in the Brassicaceae (mustard family) grows from *rhizomes* or adventitious root-buds that produce tall, leafy stems topped with heads of abundant small white-petalled flowers in late spring and pale tan seeds in summer (**Figure I-5**). Heads release clouds of pollen when disturbed, suggesting that pollination may occur independently of insects. Seed production is extremely high; each shoot can produce thousands of seeds, and the *marsh* surface beneath canopies of this species can become covered with ripe seed. Above-ground stems and leaves tend to die back by early summer after the plant produces seed, but in favorable conditions a second crop of flowering stems can replace them. In *tidal* salt marshes of San Francisco Bay, *Lepidium latifolium* is found along the high *marsh* edge, especially in disturbed areas, deposits of sand or *tidal* litter, or *levee* slopes. In *brackish tidal*marshes with lower *salinity* it invades the middle *marsh* plain and channel edges, often forming large swards. It can even dominate the vegetation in entire marshes. *Lepidium latifolium* colonies expand more rapidly and establish with increased frequency in years of high rainfall (Baye pers. comm. 2004).

May (1995) noted that *Lepidium latifolium* invasion is generally restricted to areas with *freshwater* input in the southern *estuary*, and is most abundant in the northern *estuary*, where *salinity* levels are lower. A survey (Grossinger *et al*. 1998) found *Lepidium. latifolium* in the following areas within the *estuary*:

North Bay: Potrero Hills area (especially Rush Ranch), along *tidal* channels and the upland margin of *tidal* marshes; Contra Costa shoreline marshes along natural channels and mosquito control ditches; Suisun Marsh (especially Grizzly Island Wildlife Area), in high *tidal marsh* areas and *diked seasonal wetlands*; Southampton Bay; Montezuma Slough; Mare Island; San

Pablo Bay, in marshes of the northeastern shore; Tolay Creek, lower reach; Petaluma River, lower reach marshes; Petaluma Marsh, along *berms*, *levees* and creek banks; Hamilton Air Field, *marsh* bordering air field; Miller Creek.

Central Bay: Strawberry Creek (Berkeley), on the beaches at the creek mouth; Pt. Pinole; China Camp; Arrowhead Marsh (San Leandro Bay), in the higher inter*tidal*marshes; Hayward area, marshes with restricted *tidal* influence; Old Alameda Creek, surrounding areas.

South Bay: Coyote Creek, adjacent marshes; Warm Springs Marsh, on *dikes* and in *Sarcocornia marsh*; Alviso Slough; Guadalupe Slough; Charleston Slough.

Lepidium latifolium is also a widespread weed of the Sacramento-San Joaquin delta, and *alkaline* or *subsaline* grazing land and cropland in interior California (M. Renz pers. comm. 1999). It has not yet been recorded in abundance in *tidal* marshes outside of the Golden Gate, but a few individuals have been detected along *tidal marsh* edges of southern Tomales Bay, Marin County (P. Baye pers. observ. 1998).

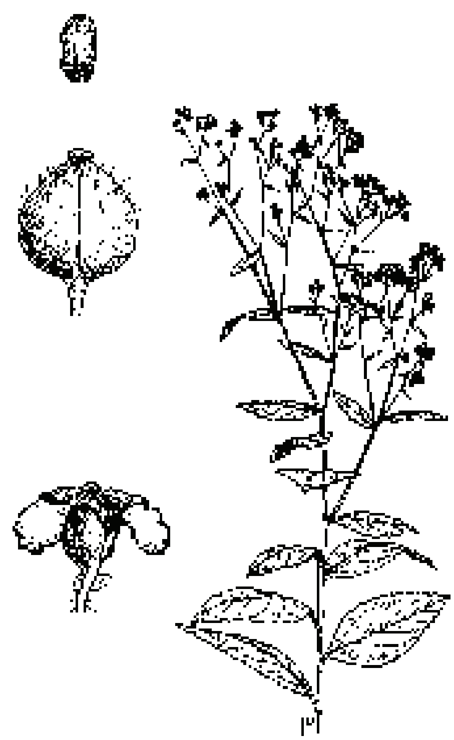


FIGURE I-5. *Lepidium latifolium* (reprinted from Invasive Plants of California's Wildlands, edited by C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, with permission from University of California Press © 2000)

Lepidium latifolium appears to be a major threat to rare plant species of the *estuary* (Howald 2000, Spautz and Nur 2004, Baye pers. comm. 2004; Grewell pers. comm. 1997-2000). In

California *tidal* marshes, *Lepidium latifolium* is actively displacing several endangered plant *populations*, including *Cordylanthus mollis* ssp. *mollis* and *Cirsium hydrophilum* var. *hydrophilum,* and reducing biomass and stature of perennial pickleweed habitat that supports other native wetland dependant species (Grewell *et al.* 2007). In a study by Spautz and Nur, mallard nesting densities were reduced, and the size of song sparrow territories reduced, in *Lepidium*-invaded areas (Spautz and Nur 2004). Researchers are concerned that as the invasion progresses, growing *populations* of *Lepidium latifolium* will exclude grasses and native vegetation which may reduce food resources for wildlife (Howald 2000, Spautz and Nur 2004). Without control, *Lepidium latifolium* can be expected to spread and increase in abundance.

Manual removal, mowing, discing, and burning of *Lepidium latifolium* have failed to suppress *populations*, and may even stimulate them (M. Renz pers. comm. 1999, Grossinger *et al*. 1998). *Lepidium latifolium* mortality is high in response to applications of glyphosate in the pre-flowering stage (M. Renz pers. comm 1999), particularly in the early stages of shoot elongation (P. Baye pers. observ. 1999-2000). Glyphosate was used in the 1990s in San Francisco Bay to control the species (Grossinger *et al*. 1998). Imazapyr is also registered for use in wetlands and has resulted in higher control levels. However, it has soil residual activity. California Department of Fish and Game (Estrella *in litt*. 2008) had success using chlorsulfuron to control *Lepidium latifolium* in stands away from water. In 2007 and 2008, San Pablo Bay National Wildlife Refuge preliminarily had most success by using a mixture of imazapyr and glyphosate (U.S. Fish and Wildlife Service 2007*a*, Downard *in litt*. 2009*a*).

Salsola soda (Mediterranean saltwort) is a succulent *annual* salt-tolerant herb in the Chenopodiaceae (goosefoot family), closely related to *Salsola tragus* (Russian-thistle or tumbleweed), as well as *Sarcocornia pacifica* (pickleweed) and *Suaeda californica* (California sea-blite). It has only relatively recently been recognized in the California flora (Thomas 1975; not cited in Munz 1968, Howell 1970), and was probably introduced to San Francisco Bay in ship ballast years before its discovery. By the mid-1980s, it became widespread in the South Bay (P. Baye pers. observ. 1985), and today is widespread and locally abundant in San Francisco and San Pablo bays. The largest *population* appears to be in high salt *marsh* and within disced dredge disposal ponds at Mare Island, San Pablo Bay, where it unevenly occupies hundreds of acres that serve as a significant seed source for the region. San Francisco Bay is apparently exporting seed of *Salsola soda*; small colonies have been detected in Drake's Estero and Bolinas Lagoon (P. Baye pers. observ. 1998). *Salsola soda* tends to be confined to *driftlines* and disturbed high *marsh*, but is widespread in low density in the *marsh* plain at Dumbarton Marsh near Newark (P. Baye unpubl. data 1999). It is a potential threat to endangered, rare, or declining plant species of high *tidal marsh*.

Other exotic plant species. There are a number of other exotic plant species that are more restricted in distribution and abundance in central and northern California *tidal* marshes. These can have significant local impacts where they occur, especially in high *marsh* zones. Some of the notable exotics include the following:

- *Carpobrotus edulis* (iceplant, hottentot-fig, sea-marigold) and its hybrids with *Carpobrotus chilense* are locally important weeds in *tidal marsh* edges, such as at Morro

Bay (P. Baye unpubl. data 1997-2000), as well as a severe problem in coastal strand vegetation in California.

- *Lotus corniculatus* (birdsfoot-trefoil) can become locally dominant in high *marsh* zones of *brackish tidal*marshes in the San Francisco Bay Estuary, as well as maritime salt *marsh* edges north of the Bay area.
- *Lythrum salicaria* (purple loosestrife) is an extremely *invasive* forb of *freshwater* marshes of the central and eastern United States. It escaped from cultivation in ornamental horticulture, and has marginally established in the Bay area. The species is beginning to invade fresh-*brackish tidal*marshes here.
- *Polypogon monspeliensis* (annual beard grass) is associated with seasonally ponded depressions, and is extremely dense locally in high *tidal marsh* zones, particularly in cattle-trampled areas or in depressions. It can become locally abundant to dominant in *brackish* marshes, especially in depressions and *salt pans* in high rainfall years.
- *Atriplex semibaccata* (Australian saltbush) is a naturalized saltbush species from Australia. It can become locally common to abundant near the high *tide* line of disturbed *tidal marsh* areas, mostly on *levees* or *berms* in San Francisco Bay.

The list above is not exhaustive, some additional *invasive* species are discussed under threats to particular *tidal marsh* regions or species in section II. Species Accounts below and new introductions may result in establishment of additional exotic *invasives* of concern.

Some native *tidal marsh* plant species can become unusually abundant or dominant over large areas because of environmental changes, such as rapid sedimentation or climate-driven shifts in *salinity*. Some are perceived by *marsh* managers to be problematic because of conflicts with specific management objectives, although this is primarily a concern for *diked* waterfowl marshes, not *tidal* marshes. *Phragmites australis* (common reed), *Typha latifolia, T. dominguensis, T. angustifolia*, and intermediates (cattail ssp.), and even *Distichlis spicata* (saltgrass) or *Sarcocornia pacifica* (pickleweed) are the objects of local suppressive management actions. These management conflicts should not be confused with invasion problems of *non-native* species. Conversely, some managers of Suisun Marsh wetlands deliberately promote the growth and spread of *non-native* vegetation (*Echinochloa* spp. [millet], *Cotula coronopifolia* [brass-buttons], *Chenopodium chenopodioides* [small red goosefoot], and reportedly *Chenopodium album* [white goosefoot], which they presume are favored by waterfowl more than natural habitats such as submersed aquatic vegetation (*Ruppia* or *Potamogeton* ponds) and associated invertebrate communities.

Invertebrates. The role of *non-native tidal* invertebrates in California *tidal marsh* ecosystems is just beginning to be studied (*e.g.,* Grosholz *et al.* 2004). Feeding, tunneling, and other invertebrate activities have the potential to significantly affect the ecosystem and species. Many *non-native* invertebrates, such as the mitten crab (*Eriocheir sinensis)*, were likely introduced through discharged ship ballast water, as described further under Reasons for Decline and Threats to Survival.

Factor B: Overutilization for Commercial, Scientific or Educational purposes.

Though the commercial hunting of California clapper rail at the turn of the 20th century had a significant negative effect on its *population* numbers, by the time of listing this threat had been eliminated. Currently, overutilization of this or any of the other listed species covered in this plan, is not known to be occurring for any purpose.

Factor C: Disease or Predation

<u>Disease</u>
Ecosystem-wide disease issues are not currently known to exist.

<u>Predation</u>
Vertebrates. Predatory species of mammals, birds, and reptiles are known to take individuals and eggs of salt *marsh* native species. Some predators, such as the Norway rat, feral cat (*Felis catus*), and the red fox present in South San Francisco Bay (discussed further under Reasons for Decline and Threats to Survival in California clapper rail and California black rail species accounts), are not native to California. Others, such as raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), ravens (*Corvus corax*), gulls *(Larus* spp.), and red-tailed hawks (*Buteo jamaicensis*), may be native to the general area, yet their abundance or impact in *tidal* marshes is aggravated by human modifications of the environment, such as *dikes* providing dryland access, landfills providing an attractive nuisance, or poles or towers providing perches. Extensive discussion of predation threats is presented in Chapter II, under California clapper rail.

Factor D: Inadequacy of Existing Regulatory Mechanisms

<u>Inadequate regulatory oversight</u>
Wetland regulation policies and practices can have a great impact on *tidal marsh* habitat and species. They usually help notify the public of wetlands values and divert inappropriate development. However, these policies and practices often do not adequately consider indirect and cumulative impacts on habitat quality and *population* viability over large spatial scales and long time frames.

Many activities that are either unregulated or weakly regulated (*e.g.,* mowing, grazing, ditching) may degrade *tidal marsh* habitats on both public and private lands. Wetlands owned by the California Department of Fish and Game are managed for waterfowl hunting in the Suisun Marsh, and some remnant *tidal* marshes were considered for conversion to non-*tidal* waterfowl managed marshes as recently as the early 1990s. Wetland management practices in Suisun Marsh were in partial non-compliance with Endangered Species Act requirements in the 1990s (U.S. Fish and Wildlife Service, file information). However, they are now on a healthier recovery trajectory for the ecosystem. The Suisun Marsh Charter Group was developed in 2001 to guide management and restoration programs, as well as recovery actions for listed species in Suisun Marsh, in a manner responsive to the concerns of stakeholders and based upon voluntary participation by private land owners. As part of this effort, they have developed a program to fulfill and exceed delinquent monitoring and *mitigation* requirements. Although *Cirsium hydrophilum* var. *hydrophilum*, *Cordylanthus mollis* ssp. *mollis* and *Suaeda californica* are included in the California Native Plant Society's (CNPS) inventory of rare and endangered vascular plants of California, there are no significant statewide efforts to protect them and they are not state-listed as endangered or threatened. However, they are all included by CNPS as List 1B species which necessitates their consideration during assessments in accordance with the California Environment Quality Act.

Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

Risk of small populations

Small *populations* are typically at greater risk of extinction than larger ones (Terborgh and Winter 1980, Diamond 1984, Pimm *et al.* 1988, Morris and Doak 2003). Because California *tidal marsh* species have lost so much habitat, their *populations* are much reduced in size. There are many causes of the increased risk of extinction characteristic of small *populations*. For example, small *populations* have increased vulnerability to extinction due to *catastrophic* events like severe droughts, storms, fires, pollution spills, *non-native* species invasion, or epidemics (Schonewald-Cox *et al.* 1983). Another factor is natural variability in birth and death rates: a chance cluster of years of high death rates or low birth rates is likely to result in the extirpation of small *populations*. At low *population* sizes, *genetic* and evolutionary effects become important, including loss of *genetic* diversity due to *founder* effects, *genetic* drift, *inbreeding,* and *inbreeding* depression.

Contaminants

Environmental contaminants may adversely affect the survival, growth, reproduction, health, or behavior of species. Some contaminants may affect a narrow range of organisms while others, like petroleum products, can impact a broader range of organisms. Known contaminants of concern in the San Francisco Bay Estuary include mercury, selenium, polychlorinated biphenyls (PCBs), organochlorine and organophosphate pesticides, dioxins/furans, polycyclic aromatic hydrocarbons (PAHs), and tributyltin from anti-fouling boat paints (see SWRCB 303d list, Region 2; Oros and Hunt 2005; Schwarzbach *et al*. 2006; Adelsbach and Maurer 2007). Ammonia and pyrethroid insecticides have become a recent concern. In addition, newly emerging contaminants which may act to disrupt endocrine systems, such as polybrominated diphenyl ethers (PBDEs) and phthalates, are being detected in the *estuary's* water, *sediments*, and biota (Oros *et al*. 2005, Oros and Hunt 2005) and are poorly understood. Unmonitored contaminants in San Francisco Bay include such chemicals as pharmaceuticals, plasticizers, flame retardants, and detergent additives (San Francisco Estuary Institute 2000). Toxic effects of many of these chemicals to rails and other *estuary* biota are not known. In other species, some of these chemicals have caused endocrine disruption and altered gender development through *in ovo* exposures (Colburn and Clement 1992). While the full impact of these emerging contaminants on species in the *estuary* remains to be determined, the increasing frequency at which they are being detected is cause for concern. All of the contaminants mentioned above have the potential to adversely impact biota in the *estuary*, depending on the extent and degree of contamination (Phillips 1987). Three of the primary known threats are described in further detail below.

The San Francisco Bay Estuary has many potential sources of petroleum and petroleum-byproduct (*e.g.,* PAHs) releases, due to a high degree of urbanization, with six oil refinery complexes, substantial ship and oil tanker traffic, and a large number of gasoline, diesel, or fuel oil-powered vehicles. PAHs are commonly detected in bay waters and *sediments* where *tidal marsh* species may be exposed to them (Ross and Oros 2004). Exposure of *tidal marsh* species to free petroleum products generally occurs as a result of vessel- or pipeline-related oil spills. As is known from numerous spill events, even relatively small exposures to oil can harm or kill birds and other wildlife (Gilardi and Mazet 1999).

The *estuary's* aquatic and aquatic-dependent wildlife species are the most at risk from contamination by bioaccumulative pollutants such as mercury and selenium. Historically, the major source of mercury contamination in the San Francisco Bay-Delta was mine waste and drainage from Coast Range mercury mines and Sierra Nevada Range gold mines (San Francisco Estuary Regional Monitoring Program 1996). Substantial reservoirs of this toxic metal left over from mining activities remain in *estuary sediments*, as well as in *sediments* and soils associated with upstream tributary water bodies. Even today, mercury from these upstream sources continues to wash downstream into the *estuary* (California Regional Water Quality Control Board 2004). However, other significant sources of mercury have been identified as being of concern. Mercury released into the atmosphere through oil and coal combustion and through waste incineration can be re-deposited into aquatic ecosystems through precipitation, contaminating water bodies with no other known mercury inputs (Wiener *et al*. 2002). Once in the aquatic realm, certain conditions (*e.g.*, anoxia and sulfate-reducing bacteria) may allow for the transformation of inorganic mercury into methylmercury, an organic form that is highly toxic and much more bioavailable than the inorganic precursor. Under continuous exposure in a contaminated ecosystem, methylmercury is introduced into the body at a much faster rate than the body can eliminate it, and aquatic and aquatic-dependent organisms bioaccumulate it into various tissues. Methylmercury concentrations in aquatic ecosystems biomagnify in each successive *trophic* level, from primary producers to the top predators (Wiener *et al*. 2002). *Tidal* marshes often exhibit the conditions that promote methylation of mercury, and high mercury concentrations have been found in a variety of fish from the San Francisco Estuary (Greenfield *et al*. 2003).

Based on egg injection work and assessments of the rail's current reproductive status, it has been estimated that observed adverse effects, in the form of developmental abnormalities and reproductive harm are seen above 0.2 ppm fresh wet weight (fww) methlymercury in rail eggs (U.S. Fish and Wildlife Service 2003). Mercury was detected in all 64 fail-to-hatch eggs collected from six Bay Area marshes in 1992. Mean mercury concentrations among marshes ranged between 0.27 and 0.79 ppm (Schwarzbach *et al*. 2006). Methylmercury was, on average, 95% of the total mercury concentration found in eggs with a 95% confidence interval between 89 and 100% (Schwarzbach *et al*. 2006).

Selenium, another bioaccumulative element, can contaminate aquatic ecosystems through a variety of human activities, including fossil fuel combustion, mining and manufacturing processes, and irrigation of seleniferous soils (Maier and Knight 1994). All of these sources may be contributing to the selenium contamination observed in the *estuary*, with agricultural drainage of lands from the west side of the San Joaquin Valley and discharges from local oil refineries the two primary sources (Presser and Luoma 2007). A *non-native* clam (*Potamocorbula amurensis*) that is abundant in the *estuary* has been shown to bioaccumulate selenium at a higher rate than crustacean zooplankton, and several predators of these bivalves have tissue selenium concentrations above thresholds thought to be associated with *teratogenesis* or reproductive failure (Stewart *et al*. 2004). The selenium contamination of the *estuary's* bivalve food web may pose a threat to bottom-feeding animals, such as the white sturgeon (*Acipenser transmontanus*), surf scoter (*Melanitta perspicillata*), and Sacramento splittail (*Pogonichthys macrolepidotus*) (Presser and Luoma 2007, Linville *et al*. 2002, Stewart *et al*. 2004, Teh *et al*. 2004). In fact, deformities typical of selenium-induced *teratogenesis* have been observed in Sacramento splittail (Stewart *et al*. 2004).

Oil spills in San Francisco Bay have potential to cause serious consequences to sensitive *tidal marsh* species. As a consequence of the *catastrophic* oil spills of 1989, the Oil Pollution Act of 1990 required contingency plans be completed by both State and Federal Governments. The U.S. Coast Guard and California Department of Fish and Game – Office of Spill Prevention and Response agreed to joint preparation of contingency plans. The Area Committee planning process is a proactive effort to deal with potential oil releases inherent in California's petroleum dependant economy and culture. This planning process is open to all stakeholders and has involved representatives from over 50 agencies, including environmental groups, city and county planners, California State agencies, the Federal government, and Industry. These organizations have come together to produce a landmark comprehensive planning document that serves as a "one stop" marine pollution response plan for the three port areas and the included six geographical sections of the California Coast (North Coast, San Francisco Bay and Delta, and Central Coast/Monterey) (U.S. Coast Guard *in litt*. 2009). The three Area Contingency Plans provide guidance for the first 24 hours of response and are living documents, the respective area committees meeting regularly to update, review, and revise the documents as needs become apparent.

More information regarding contaminants and their observed and potential effects to sensitive wildlife can be found in **Appendix E**.

Global warming and climate change

California *tidal* marshes are expected to be subject to the effects of global sea level rise and climate change due to global warming (Knowles and Cayan 2002). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007), global sea level rose by about 120 m (400 ft) during the several millennia that followed the end of the last ice age (approximately 21,000 years ago), and stabilized between 3,000 and 2,000 years ago. Sea level indicators suggest that global sea level did not change significantly from then until the late 19th century. The instrumental record of modern sea level change shows evidence for onset of sea level rise again during the 19th century. Estimates show that during the 20th century global average sea level rose at a rate of about 1.7 mm (.07 in) per year.

Satellite observations available since the early 1990s provide more accurate sea level data with nearly global coverage. This satellite altimetry data set shows that since 1993, sea level has been rising at a rate of approximately 3 mm (.12 in) per year, significantly higher than the average during the previous half century (IPCC 2007). It has been suggested that the climate system, particularly sea levels, may be responding to climate changes more quickly than the models predict (Heberger *et al.* 2009). Additionally, most climate models fail to include ice-melt contributions from the Greenland and Antarctic ice sheets and may underestimate the change in volume of the world's oceans.

According to a 2009 study conducted by Pacific Institute, under medium to medium-high emissions scenarios, mean sea level along the California coast will rise from 1.0 to 1.4 meters by the year 2100 (**Figure I-6**). Other key findings of the study report that a 1.4 meter sea level rise would flood approximately 150 square miles of land immediately adjacent to current wetlands and would result in accelerated erosion resulting in a loss of an additional 41 square miles of California's coast by 2100 (Heberger *et al.* 2009).

Other effects associated with warmer climate and higher sea level include more extreme storm events and greater extremes of wave height and energy (Wilkinson 2002, Bromirski *et al.* 2004) and lower amounts and altered timing of *freshwater* inflow (Knowles and Cayan 2002). In fact, in most cases, more extreme storm events present a far greater near-term threat to local *populations* than sea level rise (Downard *in litt*. 2009*b*). The effects of past *subsidence* of *diked marsh* areas (Atwater *et al.* 1979) are likely to be amplified by rising sea level, making it harder to restore some subsided areas to *tidal marsh*.

The effects of rising sea levels on *tidal* marshes are dependent upon the relative rate of sea level rise versus rates of sedimentation and *accretion* of the *marsh* surface. Unless a balance between sedimentation/*accretion* and erosion/*subsidence* is met that equals or exceeds the rate of sea level rise, there will be a net loss of salt *marsh* habitat. It remains uncertain whether *accretion* will keep pace with accelerated sea level rise and other climate-related effects; California's *tidal* marshes may either rise with rising sea level, or erode or drown (Orr *et al.* 2003).

The maintenance of *tidal marsh* habitat area during sea level rise requires (1) space for *tidal* marshes to expand upward into adjacent habitats as sea and *tide* levels increase; (2) available *sediment* adequate to support *marsh accretion* rates equal to or greater than the rate of sea level rise; and (3) stable erosion rates, or at least rates that do not defeat *marsh accretion*. The first of these requirements—room for marshes to "move up" in elevation—is especially problematic in the many areas of the San Francisco Bay Estuary where *tidal marsh* abuts a *dike*, *levee*, seawall, or other human barrier at its landward edge. The requirement for moderate erosion rates is also of concern, given that climate change and sea level rise in California are expected to be accompanied by increased storm severity and maximum wave heights; trends that are already suggested by available data (Wilkinson 2002, Bromirski *et al.* 2004). *Sediment* supply for *marsh accretion* is not yet well understood.

Sea level rise will cause *salinity* levels to increase up the *estuary* as *tides* push higher up bays, rivers, and *sloughs*. For example, Suisun Bay and the Delta may become saltier. Species that prefer *brackish* conditions over salt marshes would presumably suffer reduction in habitat, while salt *marsh* species might expand into Suisun Bay and even the Delta. Closer study is needed of the potential amount and extent of *salinity* and habitat change, and the species-level effects of these changes.

Overall, threats from global climate change to *tidal marsh* habitats and species in California include: (1) habitat loss where landward migration of *tidal marsh* plant communities is prevented by artificial or geographic barriers, or where sea level rise or erosion exceeds sedimentation; (2) *salinity gradients* migrating up-*estuary* as *tidal* inundation increases; (3) greater extremes of heat and desiccation stress on wetland plants; (4) the loss and/or decreased *fecundity* of rare *populations* and species (Reid and Trexler 1991, Boorman 1992, Keldsen 1997); and (5) high mortality rates associated with extreme weather events (Downard in litt. 2009*b*).

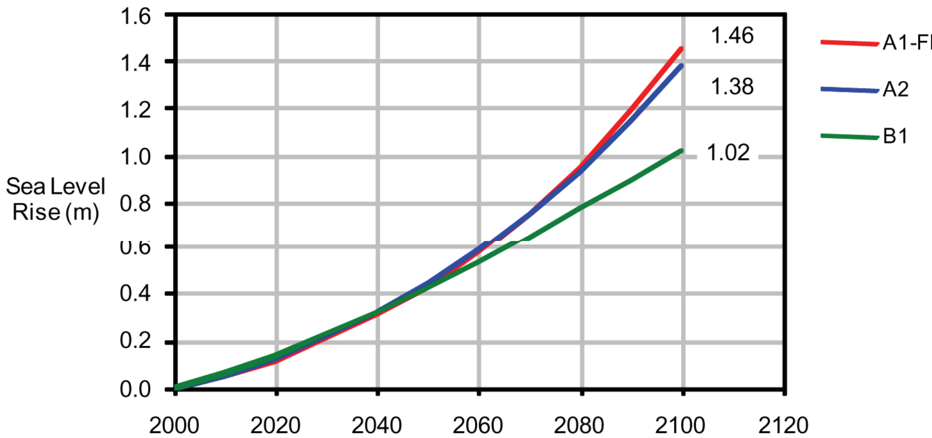


FIGURE I-6. **Scenarios of sea-level rise to 2100** (Cayan *et al.* 2009). Estimated overall projected rise in mean sea level along the California coast for the B1 and A2 scenarios of 1.0 meter and 1.4 meters, respectively, by 2100. The A1FI scenario assumes a continued high level use of fossil fuels. (Source: Dan Cayan, Scripps Institution of Oceanography, NCAR CCSM3 simulations, Rahmstorf method.)

Incomplete understanding of recovery needs

As we note in Chapter II, none of the species covered by this draft recovery plan is completely understood. Recovery and conservation actions considered most urgent and most beneficial must be implemented, but in the absence of full understanding, actions may fail to help certain species, or even inadvertently set back their recovery. In these situations, ecosystem restoration is clearly a benefit, thereby letting species recover along with their ecosystem. However, this approach alone is not adequate. The Service and its partners will promote research, gather further information, and develop a better understanding of species' and ecosystem recovery needs to better plan and undertake recovery and conservation work.

Combined factors. Few of the above causes of habitat degradation are independent of one another; rather, they interact. For example, construction and subsequent maintenance of a *dike* may restrict *tidal* circulation, focus the impacts of any fresh wastewater discharges, provide predator *corridors* and nest/den sites, compress high-*tidal* refugial vegetation to a narrow strip, and promote weed growth. It may also mobilize contaminants buried in *marsh sediments*. The presence of the *dike* may provide recreational access for people and their pets, potentially causing increased disturbance and litter attractive to animal pests.

In summary, the above overarching threats of habitat loss and fragmentation, habitat degradation and disturbance, *invasive non-native* species, predation, risk of small *populations* and climate change affect the *tidal marsh* ecosystem upon which the species covered in this draft ecosystem depend. Many of these threats are severe and immediate and most are combined with additional threats to individual species, discussed in the respective species accounts in Chapter II.

E. Tidal marsh conservation, restoration, and management

Tidal marshes in California today are the focus of numerous diverse conservation efforts. Many significant preservation, restoration, management, education, monitoring, and research projects are being planned or are underway, and new initiatives are emerging continuously. Any attempt to catalog these efforts here is certain to be dated by the time of publication, and to neglect many important participants and projects. Therefore, with appreciation and apologies to the other partners in conservation, this section is limited to a selective review of conservation of California *tidal marsh* environments for emphasis of certain principles or historical developments. Other organizations and agencies offer useful information about *tidal marsh* conservation efforts. Their contact information, including weblinks, is available in **Appendix D**. Specifically, the San Francisco Estuary Institute's Bay Area Wetland Project Tracker, San Francisco Bay Joint Venture, Bay Conservation and Development Commission, San Francisco Bay Wetlands Restoration Program, Invasive Spartina Project, South Bay Salt Pond Restoration Project, and Suisun Marsh Program websites contain extensive information and maps about *tidal marsh* conservation and projects around the San Francisco Bay Estuary.

Following increased public awareness of *tidal marsh* destruction in the 1960s, public agencies (primarily the California Department of Fish and Game and the U.S. Fish and Wildlife Service, but including regional conservation districts, state and regional parks, and the State Lands Commission) acquired title to and protected many remaining *tidal* marshes throughout the San Francisco Bay Estuary. *Tidal* marshes in public ownership at Greco Island, Mowry and Dumbarton Marshes, Petaluma Marsh, Fagan Slough Marsh, Rush Ranch, China Camp, Point Pinole, Southampton Marsh, and Hill Slough contain irreplaceable pre-historical *tidal* marshes. These agencies also acquired many *diked* baylands under threat of development to reserve them for future restoration to *tidal marsh* (*e.g.,* Cullinan Ranch, Vallejo; Bair Island, Redwood City; Baumberg Tract, Hayward; Bel Marin Keys, Novato; Hamilton Field, Skaggs Island, etc.). Currently, restorations totaling more than 4,000 hectares (10,000 acres) have been completed and over 4,000 hectares (10,000 acres) more are in the planning phase (www.wetlandtracker.org). During the 1990s, the scale of proposed restoration projects generally increased from tens of acres typically in a *mitigation* context, to hundreds and thousands of acres in a restoration context. Current projects range from simple *dike* breaching to the use of dredge spoil to raise subsided historic baylands to elevations suitable for *marsh* establishment.

Many historically *diked* baylands have reverted to *tidal mudflats* and *marsh* following accidental or deliberate restoration of *tidal* flows. During the 1930s, unrepaired *levee* breaches caused the spontaneous restoration of *tidal* salt *marsh* at two former salt ponds along the central Alameda County shoreline, Ideal Marsh and Whale's Tail Marsh. Today these marshes appear as mature salt *marsh*, showing only traces of their breached salt pond origins in the form of relict *berms* and ditches. *Diked* baylands at White Slough on the Napa River in Vallejo, Solano County, were accidentally breached in 1977. By the 1990s they had reverted to extensive low *brackish marsh* and *mudflat*. On the opposite shore of the Napa River, a marina left derelict in the 1950s has reverted to *brackish* low *marsh* and middle *marsh* (Pritchett Marsh, east of Guadalcanal Village). Derelict marinas at Port Sonoma and Alviso have silted in and become dense salt *marsh* and *brackish marsh*, respectively. A 200 hectare (550 acre) former salt pond (Pond 2A) in the former Leslie (Cargill) Salt Napa facility in San Pablo Bay was breached deliberately by the California Department of Fish and Game in 1995, resulting in a reactivated relict *tidal* creek network and prevalence of *Scirpus maritimus* (alkali bulrush) by 1998. In the Suisun Marsh area, spontaneous reversion to *tidal marsh* has occurred through gradual *dike* breach enlargement at Ryer Island, portions of Chipps Island, and a few other sites where low *brackish marsh* has re-established. Large fetches (open-water distances over which wind-generated waves propagate) so far have not precluded *marsh* restoration at any of the older established large restored *marsh* sites, probably because of the wave energy-damping properties of *marsh* vegetation (Woodhouse *et al.* 1976, Newcombe *et al*. 1979, Knutson *et al.* 1982, Moeller *et al*. 1996).

Many smaller *tidal marsh* restorations, mostly performed as *mitigation* for wetland destruction, have been conducted throughout the *estuary*. Some have relied on moderate to elaborate engineering (Pond 3, Alameda County; Oro Loma Marsh, Hayward; Cogswell Marsh, Hayward; Muzzi Marsh, Corte Madera; Sonoma Baylands, near Port Sonoma; Warm Springs Marsh, Fremont; LaRiviere Marsh, Newark), while others used minimal or no engineering (Toy Marsh and Carl's Marsh, lower Petaluma River; Faber Tract, Palo Alto).

The habitat quality and success rates of restored *tidal* marshes have been variable due to many factors, including maturity of the restored site, design features, site selection and environmental setting, invasion pressures by exotic species, *tidal* circulation and *sediment* supply, and initial site elevations and substrate conditions. Dredged materials have been used in some projects to raise initially low subsided elevations in *diked* baylands (Pond 3 Alameda, Muzzi Marsh, Sonoma Baylands), but placement of dredged materials to elevations approaching mean higher high water (mature *marsh* plain) appears to inhibit development of *tidal* drainage networks. Rapid development of high quality *tidal marsh* can occur with little or no engineering (Carl's Marsh, Pond 2A, Ideal Marsh, White Slough), especially given optimal starting conditions (*i.e*., not highly subsided, raised elevations, adjacent to an adequate *sediment* source). While a degree of engineering may sometimes be necessary, engineering of *tidal* restoration can be overdone, as numerous engineered *tidal* marshes have required corrective measures, developed slowly, or developed mostly habitats or vegetation other than those originally planned (Warm Springs, Sonoma Baylands, Muzzi Marsh, Oro Loma Marsh, Cogswell Marsh).

The results of both planned and spontaneous *tidal* reflooding of *diked* baylands (discussed above) indicate that *tidal marsh* restoration is highly feasible in the San Francisco Bay Estuary. The spontaneous and unexpectedly rapid restoration of low *tidal marsh* and *tidal*creek networks over very large tracts (greater than 200 hectares [500 acres]) at Pond 2A, Napa, where *subsidence* of the original *marsh* surface was only moderate, suggests high feasibility of restoring low *tidal marsh*. Similar extensive low *marsh* has developed in south San Francisco Bay at outer Bair Island (San Mateo County), breached in 1970. Middle *marsh* plains have regenerated over longer periods of time on narrower tidally reflooded *diked* baylands (Ideal Marsh, Whale's Tail Marsh). At least one large (greater than 80 hectares [200 acres]) deeply subsided and over-excavated *diked* basin (Warm Springs, Fremont) has developed *mudflats* and *brackish* low *marsh* after a decade of rapid sedimentation in a prolonged sub*tidal lagoon* phase. A few *tidal* restoration projects that had initially obstructed *tidal* circulation (Sonoma Baylands, Tolay Creek *mitigation* site) developed shallow *microtidal lagoons* with abundant submerged aquatic vegetation (*Ruppia maritima*), resulting in unexpectedly high value waterfowl and shorebird habitat similar to solar salt intake ponds. Many of the restored *tidal* marshes have been spontaneously recolonized by endangered California clapper rails and salt marsh harvest mice (*e.g.,* Toy Marsh, White Slough, Faber-Laumeister, Carl's Marsh, Ideal Marsh, Whale's Tail Marsh).

The longer-term development of middle *marsh* plains and creek bank *levees* in tidally restored basins in the face of rapid sea level rise and uncertain *sediment* supplies is less certain (Goals Project 1999; Pethick 1993, Warren and Niering 1993, Pye 1995). A high rate of sea level rise does not preclude the feasibility of low *marsh* restoration in the San Francisco Bay Estuary, but it raises the possibility that some local engineering may be necessary to speed restoration of middle and high *marsh* near the landward edges of large restored marshes.

Substantial amounts of *tidal marsh* restoration or enhancement in the San Francisco Bay area have resulted from minimization of impacts from development. In the South Bay, several sites proposed for full development in the 1980s were modified significantly to minimize areas and impacts in *tidal marsh* habitat, and provide habitat protection and enhancement over the remaining habitat. Outstanding examples are Roberts Landing (Citation Homes, San Leandro) and Mayhews Landing (Newark). In both these sites, the majority of habitat was protected and enhanced by re-engineered tidegates to improve *salinity* and moisture of salt *marsh*, while providing *tidal* drainage to prevent prolonged impounding of flood waters. Monitoring and reporting requirements of project permits were limited, however, so the long-term ecological and *population* trends of these sites will be difficult to determine.

The engineered salt *marsh* restoration at Pond 3 (Alameda Creek), among the oldest in San Francisco Bay, was constructed by the U.S. Army Corps of Engineers using dredged materials from the adjacent flood control channel. Although the project had some unanticipated and undesirable outcomes—notably spread of introduced *non-native Spartina alterniflora*—it has resulted in a large high-elevation tidally influenced *Sarcocornia marsh* and an expanded *population* of salt harvest mice. The overfilling of the site above design criteria minimized clapper rail habitat, but provided exceptionally thick *Sarcocornia* habitat that may be somewhat buffered against sea level rise, providing important refuge from extreme *tides* and storms at upper *tidal* elevations.

Renzel Marsh (ITT Marsh, Palo Alto) was protected and enhanced by the City of Palo Alto and the California Coastal Conservancy to minimize impacts of Palo Alto wastewater discharge (conversion to *brackish marsh*). The *marsh* has been re-engineered with tidegates to minimize impoundment of floodwater and hasten flood drainage, and to provide limited managed *tidal* flows to enhance *Sarcocornia* habitat for the salt marsh harvest mouse. Quality and abundance of *Sarcocornia* habitat has increased, though water management will require ongoing adjustment (Woodward-Clyde 1996, Shellhammer pers. comm. 1998).

One south San Francisco Bay *mitigation* site, the engineered *Sarcocornia* “mouse pasture” at Bayside Business Park at Warm Springs (Fremont) has been colonized by a continually low *population* of salt marsh harvest mice. The adjacent Bayside Business Park II development nearer Dixon Landing Road on Coyote Creek was configured to minimize urban fill in *Sarcocornia* habitat. The remaining *marsh* is in a long-term phased conversion from *diked* non-*tidal Sarcocornia* /salt *pan* habitat, subsided well below sea level, to a *tidal marsh* with a wide sloping high *tidal brackish marsh* zone along the landward edge. Both sites are small and relatively isolated, and the long-term outcome of this habitat restoration remains to be seen. The Pacific Commons project, also near Warm Springs (Fremont), reduced on-site impacts and preserved roughly 160 hectares (390 acres) of *vernal pool* grasslands adjacent to high *marsh* (Shellhammer pers. comm. 1998).

Around San Pablo Bay, to minimize impacts of a median barrier/shoulder widening project along the highway, the California Department of Transportation (Caltrans) engineered flood drainage enhancements to the Highway 37/Mare Island strip *marsh*, the eastern half of which suffered flooding and drainage problems caused by the intake canal *berm*. The project resulted in rapid *sediment accretion*, and decreased the depth and duration of flooding from *storm surges* and rain. The project would have restored 650 hectares (1,600 acres) to highly valued *tidal marsh* habitat. However, though initially successful, infilling and waves eventually re-built the *berm*, and the added drainage was lost after approximately 6 years (P. Baye *in litt*. 2007).

CALFED Bay-Delta Program, Delta Vision, and Bay-Delta Conservation Plan

A number of other efforts are ongoing in the Delta to conserve species and habitats:

- The CALFED Bay-Delta Program is a unique collaboration among 25 State and Federal Agencies to improve water supplies in California and the health of the San Francisco Bay/ Sacramento-San Joaquin Delta. In 2000, CALFED completed a 30-year plan that sets forth general goals and a science-based planning process for making future decisions on Bay-Delta programs and projects.

- Delta Vision was created by a 2006 Executive Order of the California Governor to find a durable vision for sustainable management of the Sacramento-San Joaquin Delta, so it could continue to support environmental and economic functions critical to the people of California. The Delta Vision Strategic Plan was completed in 2008 and recommended actions that to address the full array of natural resource, infrastructure, land use and governance issues necessary to achieve a sustainable Delta.

- The Bay-Delta Conservation Plan (BDCP) is a planning and permitting process that will manage water resources in the Delta in a way that reliably delivers water to 25 million Californians while at the same time protecting and restoring sensitive species and habitats. The BDCP is being developed in coordination with Federal and State agencies, environmental organizations, water contractors and other interested stakeholders. Once completed, the BDCP will serve as both a Habitat Conservation Plan and a Natural Communities Conservation Plan for the purposes of permitting the incidental take of protected species.

<u>South Bay Salt Pond (SBSP) Restoration Project</u>
The vision of restoration of a significant portion of the Bay's *tidal marsh* was first articulated by the Bayland Ecosystem Goals Project and is currently the subject of a large restoration planning effort. In March 2003, 6,700 hectares (16,500 acres) of salt ponds were sold by the Cargill Corporation to the California Department of Fish and Game and U.S. Fish and Wildlife Service for phased restoration as a mosaic of *tidal* salt *marsh* and nontidal managed ponds. The acquisition, which included approximately 600 hectares (1,500 acres) of salt ponds in the Napa River watershed and approximately 6,000 hectares (15,000 acres) of salt ponds in the South Bay (specifically at the Baumberg [Eden Landing], Alviso, and Ravenswood areas), will enable the largest *tidal* restoration project in west coast history, and will be the single most significant step toward California clapper rail and salt marsh harvest mouse recovery. The Record of Decision for the Final EIR/EIS (EDAW *et al.* 2007) for the South Bay Salt Pond Restoration Project was signed on January 27, 2009 (U.S. Fish and Wildlife Service 2009*b*).

The Baumberg site, formerly proposed as a racetrack and park complex (Shorelands), is a key area now protected in San Francisco Bay. This site, to be owned and managed by the California Department of Fish and Game, will add significant high quality habitat for *tidal* species as well as many species of shorebirds. While the final habitat acreage suitable as salt *marsh* habitat is yet to be determined, thousands of acres of suitable habitat for *tidal marsh* species may eventually be enhanced or restored, and existing *populations* protected. Similar phased restoration is planned for pond complexes at Alviso and Ravenswood areas, which will be owned and managed by the Don Edwards San Francisco Bay National Wildlife Refuge.

Because former salt ponds provide essential habitat for shorebirds and other waterfowl in San Francisco Bay, the importance of retaining ponded habitat for those species during the larger *tidal marsh* restoration is clear. Agreement was made by the involved scientists to strive for a dynamic mosaic of both *tidal marsh* and non*tidal* managed ponds. The Final EIR/EIS details a plan for progress toward full *tidal marsh* restoration, but, through an adaptive management framework, builds in a feedback loop via species and habitat monitoring to cease additional *tidal* restoration before non-*tidal* bird species are affected negatively.

<u>Suisun Charter</u>
The Suisun Marsh Charter Group is a collaboration formed in 2001 to resolve isses of amending the Suisun Marsh Preservation Agreement (SMPA), obtain a Regional General Permit, implement the Suisun Marsh Levee Program, and recover endangered species. The Charter Group was charged with developing a regional implementation plan that would outline the actions needed in Suisun Marsh to preserve and enhance managed *seasonal wetlands*, restore *tidal marsh* habitat, implement a comprehensive *levee* protection/improvement program, and protect ecosystem and drinking water quality.

The *Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh* would be consistent with the goals and objectives of the Bay-Delta Program, and would also balance them with the SMPA, Federal and State Endangered Species Acts, and other management and restoration programs within the Suisun Marsh in a manner responsive to the concerns of all stakeholders, and based upon voluntary participation by private landowners. The proposed *Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh* would also provide for simultaneous protections and enhancement of (1) the Pacific Flyway and existing wildlife values in managed wetlands; (2) endangered species; (3) *tidal* marshes and other ecosystems; and (4) water quality, including, but not limited to, the maintenance and improvement of *levees*.

In addition, as of 2007, a total of 2,500 acres (1,012 hectares) made up of twelve individual parcels owned by the California Department of Fish and Game (10), the Suisun Resources Conservation District (1), and the Department of Water Resources (1) are managed as Mouse Conservation Areas. The establishment of these areas was a requirement of the U.S. Fish and Wildlife Service's 1981 biological opinion (U.S. Fish and Wildlife Service 1981) on the Suisun Marsh Management Plan, a plan developed by the U.S. Bureau of Reclamation and California Department of Water Resources to discuss development of a number of water conveyance facilities that would change the "major intake for *marsh* water supplies from Grizzly Bay to the Sacramento River near Collinsville, by introducing municipal waste water, and by redistributing water in major *marsh* channels".

The biological opinion specified via a conservation measure that the agencies set aside at least 2,500 acres of preferred salt *marsh* harvest mouse habitat to protect the species from the project impacts. These Mouse Conservation Areas are surveyed every three years to monitor salt *marsh* harvest mouse *populations*. In addition, aerial surveys are flown every three years to monitor preferred mouse habitat throughout the *marsh* and determine if pickleweed habitat is being lost. Other habitats used by salt marsh harvest mice in the Mouse Conservation Areas are not, to date, being assessed for vegetation change.

Invasive Spartina Project

The California State Coastal Conservancy established the Invasive Spartina Project (ISP) in 2000. The overall goal of the project is to develop a regionally coordinated project to address the rapid spread of four introduced and highly *invasive Spartina* (cordgrass) species in the San Francisco Estuary. The ISP surveys the Bay annually to assess and map the distribution of introduced *Spartina* species. The project collects location and ecological data for each found *population,* then plant material is sent to the UC Davis Spartina Lab where *genetic* testing is conducted to confirm identification of *S. alterniflora* hybrids. All collected data are integrated into a Geographic Information System (GIS) layer for analysis, and used in planning the regionally coordinated *Spartina* control program. The control program, the action arm of the ISP, is coordinated by contractors and staff of the ISP, and implemented by the many land managers, land owners, environmental groups, and others who are working to arrest and reverse the invasion of *non-native* cordgrasses in the San Francisco Estuary. For a calendar of past and future treatment events, please see the ISP website, listed in **Appendix D**.

Other vital *tidal marsh* conservation efforts, carried out by numerous organizations and agencies including the Service, involve public outreach, education, management (including *invasive* species control), monitoring, and research.

Given that restoration of *tidal marsh* ecosystems is a continuously evolving science, and that an authoritative guide to the latest understanding and sources about restoration of *tidal* habitats is available (Philip Williams and Associates, Ltd. and Faber 2004), technical prescriptions for *tidal marsh* restoration methods will not be offered here. The Bayland Ecosystem Goals Project (Habitat Goals, notably chapter 6: 1999) also reviews restoration considerations, past projects, and lessons learned (Goals Project 1999).